SECTION F: Non-Soil Based Treatment Systems

Choosing Technology for Onsite Systems

Conventional onsite technology consists of a septic tank and gravity flow to a series of soil treatment trenches. New choices have become available in recent years, including sand filters, peat filters, constructed wetlands, mechanical aerobic, drip irrigation, and variations on both the conventional septic tank and the conventional soil treatment system. Using combinations of technologies, figuring out which choices are best suited to different sites, and sizing systems using these new technologies can be confusing.

Performance/Alternative

The bottom line in selecting any of these technologies is making sure the wastewater is treated before it's discharged into the environment. Another way to look at treatment is to think of getting rid of the problems before the water is *used* again. Once the goals of treatment are established, such as the removal of pathogens and nutrients, various technologies can be analyzed for their effectiveness. For instance, the conventional choice (a septic tank and trenches with at least three feet of soil separating the system from bedrock or saturated soil) does an excellent job of removing all of those problems.

Performance standards for treatment of septic tank effluent are based on these conventional systems: The performance goal of any new technology should be to do as well as a conventional system measured at 3-foot below the trenches. Numerically, the standards are zero fecal coliform, less than one milligram per liter phosphorous, and a nitrate level lower than drinking water standards before the water reaches the environment.

Once it's been established that a technology can provide the desired level of treatment, the next criterion is reliability. In analyzing reliability, identify the part(s) of the system where things could go wrong. When one component of the system fails or breaks, will it alter or shut down the treatment process? As an example, consider aerobic treatment units. An aerobic treatment unit functions very well as long as it's getting air. As soon as the air is turned off, it's no longer an aerobic treatment unit--it becomes a septic tank very quickly. The design of a septic tank and an aerobic treatment unit are significantly different. Most aerobic units can't function as conventional septic tanks. The addition of air is critical to the reliability of the aerobic system.

Regular monitoring of its operation is necessary to make sure the aerobic treatment unit is operating the way it is intended. If a component is easily broken, it's not reliable. That doesn't mean it can't be chosen, but there must be a comprehensive management plan in place that includes frequent monitoring and regular maintenance of the less-reliable parts of the system.

Management of the System

Management is taking care of the entire system, through both **operation** and **maintenance**. Operation is the day-to-day upkeep of the system, and every system will have some operational requirements.

Maintenance is the attention to the routine critical processes of the system that ensures the proper operation and long life, such as changing the oil in your car or tractor. A conventional septic system has a three-part maintenance requirement: using the right amount of water; pumping the septic tank at regular intervals (typically once every two years); and staying off of or otherwise protecting the soil treatment area. Newer technologies have more demanding management requirements.

An aerobic treatment unit's requirements are similar to, but more complicated than those of the conventional septic tank are. Not only must it be pumped out periodically, but also it must also always be receiving air. The most critical maintenance practice is to be sure that air is entering the tank. Reliability and management are connected; in this case, airflow has to be checked and any problems quickly rectified for the aerobic treatment unit to be reliable. Each of the new technologies has its own maintenance requirements.

Another aspect of management is also related to reliability: **monitoring.** Every system has to be checked to see that it performs as designed. Monitoring can involve additional steps in critical areas such as lakeshore, coastline and source water protection areas. It may require periodic sampling before the effluent is discharged.

A final important aspect of management is replacement. As an onsite system wears out, it must be fixed. In a conventional system, replacement is the responsibility of the homeowner and occurs every twenty to forty years. With new technologies and new models of system management, as each part of a system is replaced, it can also be updated, possibly minimizing the expense of total replacement by prolonging system life.

Designing with Management in Mind

How can the designer of these systems relate technology and management? In the past, there was a standard technology (septic tank and three feet of soil) and standard management (pumping the tank every two to three years). With the new choices, that's no longer the case. New technology is forcing new management strategies. As each new option is added to a system, the management of that system must change. If it doesn't, the system won't work the way it's intended to. For those systems that need additional management to ensure reliability, an adequate management plan is critical. *Management strategies must be specific to the treatment system.*

The converse is also true: the management available will limit the technology chosen. If proper management isn't in place, problems with the system will show up very quickly. An example of this maybe a holding tank, which stores wastewater and has to be pumped as soon as it becomes full. Under the old management schedule, the holding tank was pumped every two years—not nearly often enough. A holding tank may fill in two weeks! The management needs of the holding tank were higher than the level of management available. The holding tank, which was a fine technology, became limited in its application because the cost associated with hauling the sewage away for final treatment.

Before a technology is chosen, the costs, management requirements, reliability, performance, and future plans all must be considered. When designing a new system, all of the pieces need to fit together, so the system will work well into the future. An example of lack of planning is the situation where all of the small house lots on a lake are each responsible for their own wastewater treatment. If every lake had a central treatment plant, and each house had a sewer hookup, as they do in cities, the small lots would not pose a problem. Many were plotted before running water and electricity was available. These new life-style choices were not considered when these lots were plotted, and now the current owners are paying the price.

Cost

The cost of solving these problems has two parts: the cost of the technology (taking into account the reliability and longevity of the system) and the cost of the management (taking care of it). Both kinds of costs need to be considered "up front" in the planning process. All of the information on new technologies—performance, longevity, management, and flexibility—needs to be considered in order to make the right choices for each specific location.

Consider:

- Cost Management
- Reliability
- Performance
- Future

PART II: SAND FILTERS

A sand filter system uses property grade and washed sand as a medium for wastewater treatment, after a septic tank (of septic tank effluent). Sand filters have been widely used around the United States, and the various sand filter types and their designs have been extensively tested and documented.

The treatment mechanisms in a sand filter are physical filtering of solids, ion exchange (alteration of compounds by binding and releasing their components), and decomposition of organic waste by aerobic bacteria. A properly operating sand filter should produce high-quality effluent containing less than ten milligrams per liter BOD, less than ten milligrams per liter TSS, and less than 200 ppm fecal coliform bacteria.

Sand filter systems can also be appropriate in the recovery of existing drainfields. Where drainfields have failed due to lack of maintenance or due to excessive organic loading, it is possible that an existing system can continue to be used if a sand filter is made a part of the treatment system.

How Sand Filters Work

Sand filter systems begin with a pretreatment device, typically a septic tank that receives wastewater from the residence or other establishment. From this device, wastewater moves to the filter. Effluent from the septic tank is introduced at the top of the filter. Pressure distribution is preferred over gravity distribution to apply the wastewater to the filter surface. Pressure distribution allows even loading over the entire filter surface, and thus maximizes treatment. After treatment in the sand filter, effluent flows to a soil dispersal area or surface discharge.

The most common design is a **single-pass** or **intermittent** sand filter, in which the wastewater enters the filter and exits after passing through the medium once. This is the simplest design, and requires the largest filter.

Gravity distribution often leads to early failure of the sand filter due to clogging at the sand surface. The clogging mat develops due to overloading in certain areas of the filter, which then spreads over the entire surface of the filter. In addition, most of the wastewater is discharged on a very small area of sand and percolates through the sand very quickly not providing the time to adequately treat the effluent.

Single-Pass Sand Filter

Effluent from the primary treatment unit, septic tank, is transmitted to a pressure distribution network within the infiltration bed of a sand filter or gravity feed system uses a distribution box and 4-inch lateral pipe. The effluent flows downward from the bed through at least two feet of filter media where it undergoes physical, chemical and biological treatment. The treated effluent is collected and either flows by gravity or is pumped to a dispersal component.

Clean sand is used in single-pass filters, often the same size as is used in mound systems. Somewhat coarser sand, such as ASTM C-33 or IDOT Concrete Sand would provide adequate treatment of the wastewater as well as better hydraulic acceptance. With ASTM C-33, however, phosphorous and nitrogen would not be removed as well as with finer sand. Coarser sand permits better aeration of the wastewater, so that the bacteria in the filter never enter the anaerobic cycle in which these nutrients are removed and treated.

Single-pass pressure dosed filters are typically designed to accept about one gallon per day per square foot of filter surface. Free access sand filters may be loaded at two to five gpd/sqft. At this higher loading rate, the system will require maintenance of the medium (replacement or cleaning of the sand) is necessary because the higher loading rate will lead to surface clogging. When the loading rate is lower, the system will operate properly for longer periods without being serviced.

Recirculating Sand Filters

If higher loading rates are necessary to reduce the size of the filter recirculating the waste water is an attractive alternative to the single-pass design. Recirculation means bringing the wastewater through the filter a number of times, allowing for continued filtering and increased bacterial decomposition.

A recirculating sand filter system contains the following:

- A recirculating tank containing a pump and related controls that distribute effluent to the sand filter and a dispersal component.
- The recirculating filter, consisting of:
  filter media (a lid), an infiltration bed, liner
  a distribution bed, an underdrain that collects filtered effluent
  and directs it back to the recirculating tank.

Effluent from the primary treatment of wastewater in a septic tank or other treatment component is transmitted to a recirculating/mixing tank. In the tank, effluent from the treatment component mixes with effluent that has been recirculated through the sand (gravel) filter. This mixture is applied by a pressure distribution network onto an infiltration bed of a specified media. The effluent flows downward from the bed into and through the filter media. Biological treatment occurs as the effluent passes the surfaces of the filter media. Treated effluent is collected at the bottom and is discharged by gravity or pressure back to the recirculating/mixing tank where the recirculating cycle begins again. As levels in the recirculating tank rise, treated effluent will be discharged to a dispersal component, either by gravity or pumping.

Recirculation systems require coarser media to accommodate higher loading rates; sand used for a single-pass sand filter would be too fine for a recirculating filter. For this reason, recirculating sand filters are also called gravel filters. A medium of 0.05 to 2.0 mm in diameter, such as bird grit 2, is a better choice, **3/8 inch pea gravel is to coarse and <u>shall not</u> be used.** Advanced treatment ideas for recirculation systems include expanded shale or expanded peat media.

Recirculation systems require constantly circulating water. Designs for recirculating filters must include a timer to regulate the loading of the system. The loading rate is usually four to five gpd/sqft, and the wastewater flows through the filter four or five times before leaving the system. This allows a smaller filter surface area to produce the same high-quality effluent as a larger single-pass filter. Another advantage of recirculation systems is that as wastewater moves through the filter, it becomes oxygenated. When it’s captured in the recirculation tank, it becomes anoxic (low in dissolved oxygen). During the anoxic cycle, bacteria can break down nitrates in the wastewater. This is a significant benefit in areas where nitrogen contamination of groundwater has been a problem.

Designing Sand Filter Systems

To determine the size of the filter, determine the volume of wastewater flow from the residence, and multiply it by the loading rate. The choice of the loading rate will affect the management of the system: at loading rates approaching three to four gpd/sqft, a single-pass filter will need regular cleaning of the sand surface (every two to three months), or clogging will prevent the system from operating.

The infiltrative surface of a single-pass pressured sand filter is typically sized using a loading rate of .80 to 1.0 gpd/sqft for pressure dosed systems. For gravity feed systems Chapter 69 allows 0.63 gpsf as a loading rate. This loading rate assumes a biomat has formed at the infiltrative surface and that a long-term application rate will occur. High strength wastes (see Chapter A) will require pretreat or lower loading rates. Figure F-4 shows different loading rates for different filters.

Figure F-4: Typical Design Values for Sand Filters

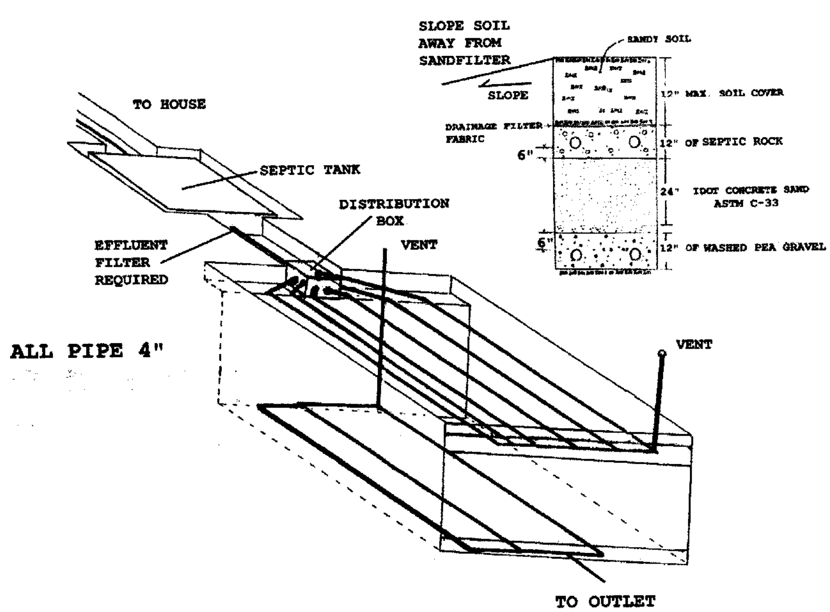
Design Factor	low-rate	high-rate	recirculating
Hydraulic Loading (based on forward flow)	< 1.0 gpd/sqft	2-5 gpd/sqft	3-5 gpd/sqft
Organic Loading	< 5 x 10^{-3} lbs. BOD/day/sqft		
Pretreatment	must include setting and removal of solids		
Media			
material	washed, durable granular material		
effective size	0.3 – 1 mm	0.3 – 1 mm	0.8 – 3 mm
uniformity coefficient	< 4.0	< 4.0	< 4.0
depth	24 inches	24 inches	24 inches
Dosing Frequency	> 6 – 12 per day	> 6 – 12 per day	5 – 10 per 30 min
Recirculation Ratio	NA	NA	5:1

The layout of the filter, in terms of length to width ratios, is not as critical as a good system of dosing, or applying wastewater to the filter surface. Ideally, the filter will receive wastewater evenly over its surface and at even time intervals. Timed dosing and a two-foot spacing of inlet pipes are recommended in many states using this system.

Single-Pass Sand Filters

Daily Flow

The recommended daily design flow for dwellings is the number of bedrooms times 150 gallons per day. For other establishments, estimate the average daily design flows using other sources. If the design flow is measured rather than estimated, you should also add a safety factor of at least 150% when sizing the system. You may want to include flow-measuring equipment in designs, including elapsed time meters and event counters.



Media for Intermittent Sand Filters

The filter media must meet the criteria specified in Figure F-5. Clean sand must be free of organic impurities and contain less than three-percent deleterious (harmful) substances. A good alternative in Iowa is the use of IDOT Concrete sand, or ASTM C-33 sand.

The minimum and optimum depth of the filter media is 24 inches. The pea gravel depth is always three inches, and the underdrain gravel depth should be a minimum of six inches.

Figure F-5: Clean Sand		
sieve number	**sieve size (mm)**	**percent missing**
4	4.75	95 to 100
8	2.0	80 to 100
10	0.85	0 to 100
40	0.425	0 to 100
60	0.212	0 to 40
200	0.075	0 to 5

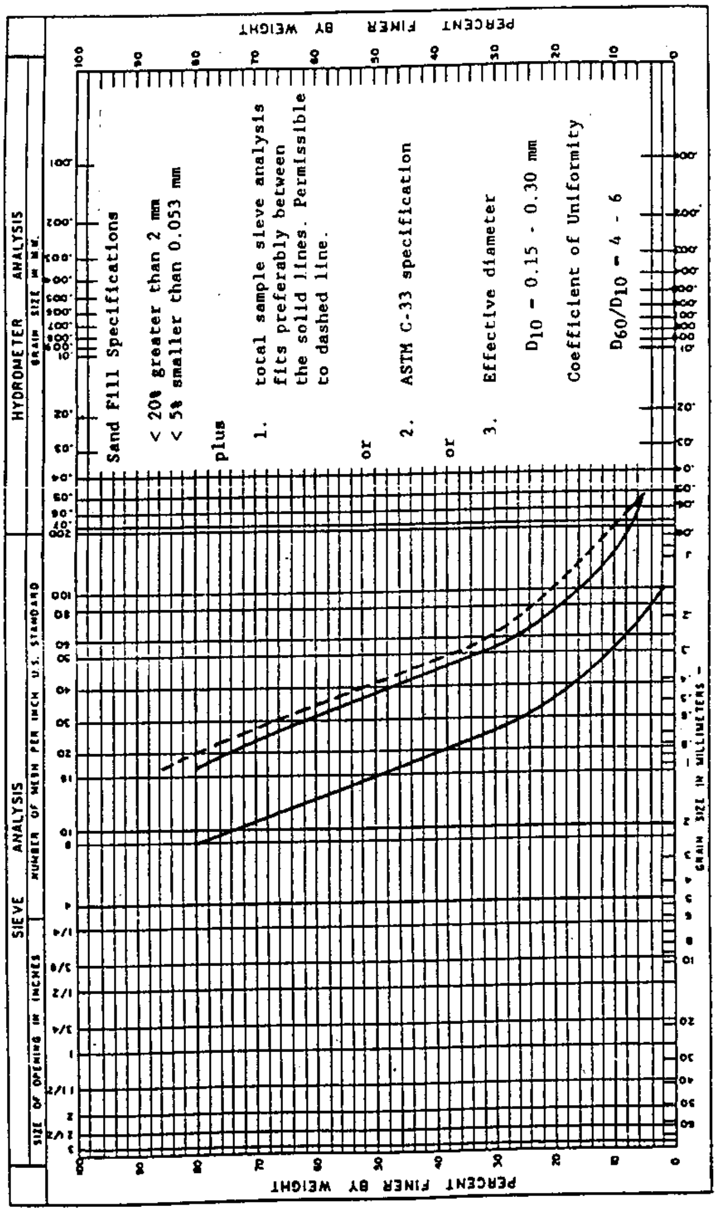
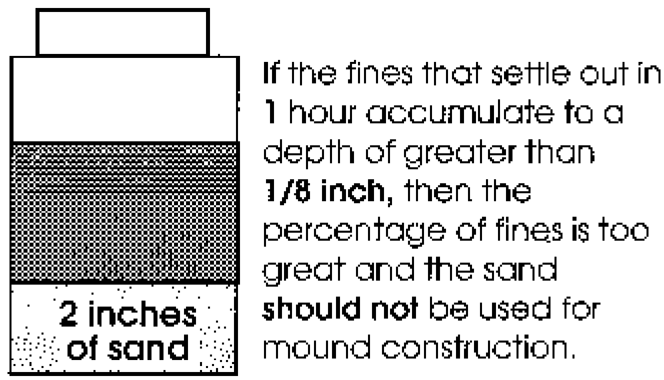


Figure 5. A guideline for the selection of the sand fill for Wisconsin Mounds. The total sample sieve analysis contains 20% or less material larger than 2.0 mm and contains 5% or less material finer than 0.053 mm plus one of the three additional specifications listed in figure. The fraction greater than 2 mm can have stones and cobbles.

This graph shows the range of sand size that is acceptable. Do not accept any sand on the fine side, error on the side of larger particle size.

Clean sand can also easily be field checked by using the jar test. Place exactly two inches of sand in the bottom of a quart jar and then fill the jar three-fourths full of water. Cover the jar and shake the contents vigorously. Allow the jar to stand for about 1 hour and observe whether there is a layer of silt or clay on top of the sand. If the layer of these fine particles is more than 1/8 inch thick, the sand is probably not suitable for use in mound construction, because too many fine particles tend to cause the soil to compact during the construction process. Also, the long-term acceptance rate of this soil will be slower than the long-term acceptance rate of clean sand, which is used for sizing the rock layers.



Place an underdrain pipe in the underdrain gravel at the same level or an inch or two above the main floor of the sand filter. This pipe should be slotted or perforated four-inch SCH 40 pipe or stronger. It should not be directly against the bottom; they should be facing 4 & 8 o'clock or, if facing six o'clock, have a few inches of gravel under the pipe.

A four-inch pipe surrounded by rock provides outflow from the filter. The depth flowline of the outflow pipe should be from one foot to 18 inches below the bottom of the sand. It is critical that the effluent drain freely out of the sand, since saturated conditions in the filter would greatly reduce its effectiveness.

Liner material specifications if needed:

- 20-30 millimeter thickness
- Manufactured per National Sanitation Foundation Standard 54.
- One-piece construction, without holes. (If a boot and a gravity-flow underdrain will be used, see Figure F-6.)

Figure F-6: Using a Boot	
If a synthetic membrane liner is used, a boot will be required.	
-	The boot outlet is to be bedded in sand.
-	The boot is to be sized to accommodate a 4” underdrain outlet pipe.
-	The boot is to be secured to the 4” outlet pipe with two stainless steel bands and screws and sealant strips as recommended by the manufacturer.
-	An inspection port shall be installed at the outlet of the underdrain pipe from the sand filter to the drainfield to facilitate checking if leakage is occurring and injecting air if needed.
-	The trench from the filter to the drainfield shall be backfilled with a minimum 5 lineal feet clay dam to prevent the trench from acting as a conduit for groundwater movement towards the drainfield.
-	Test the sand filter and boot for leakage: 1. Block the outlet pipe. 2. Fill the underdrain gravel with water. 3. Measure the elevation of the water through the inspection port. 4. Let the water stand for a minimum of 24 hours. 5. Measure the elevation of the water through the inspection port. **There must not have been any drop in the water level.**

Underdrain and Inspection Ports

Select the underdrain method, and how the effluent will be transmitted to the disposal component. In the simplest designs, effluent flows by gravity from the sand filter to the lift tank, the soil dispersal area, or surface discharge point. There are a variety of ways to design the underdrain, typically, three inches of pea gravel is placed over a six-inch layer of gravel containing the underdrain collection pipe.

If effluent is pumped directly from the sand filter to soil dispersal area, the filtrate is collected in a gravel bed underlying the filter media and is discharged into a pump basin. Provide a basin in which pump will sit, lower than the sand filter bottom so filtrate flows toward pump. This basin will usually be eight to 18 inches deeper than the bottom of filter. If a synthetic membrane is used, the pump basin must be adequately supported with a base on both sides of the synthetic membrane. The pump basin must allow the pump to stay submerged at all times.

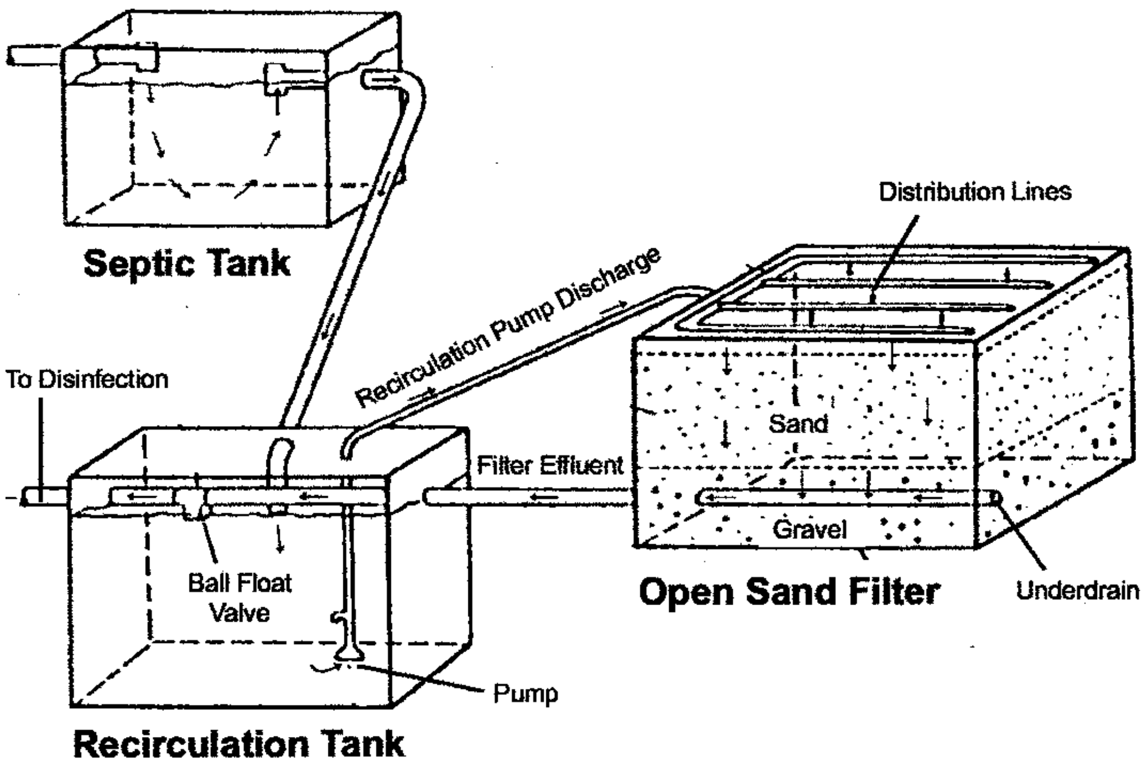
Design the Distribution Network

Pressure distribution is preferred. The required number of doses per day is between six and 12. (See **Section E: Pressure Distribution and Pumping Systems.)**

Recirculating Sand Filters

Determine Daily Flow

Recommended daily design flow for dwellings is the number of bedrooms times 150 gpd. For other establishments, estimate the daily flows using other sources. Designers are strongly encouraged to include flow-measuring equipment in designs, including elapsed time meters and event counters.



A plastic liner is required for all recirculating sand filters. To remove the impact of ground water.

Sizing

Select the filter media. It must meet these criteria:

- Particle size distribution complies with Figure F-7.
- Effective particle size: three to five mm

- Uniformity coefficient: ≤ 2
- Filter media must be washed.

Figure F-7: Particle Size Distribution for Recirculating Sand Filter Media		
sieve size	**particle size (mm)**	**percent missing**
3/8 inch	9.50	100
No. 4	4.75	0 – 95
No. 8	2.35	0 – 2
No. 30	0.60	0 – 0.1

The uniformity coefficient is defined as the ratio of D60 (grain diameter for which sixty percent the sample by weight is finer) to D10, the effective grain size (grain diameter for which ten percent of the sample by weight is finer).

Determine the required infiltrative surface area (the interface between gravel and sand). The loading rate is calculated on the basis of the BOD of the septic tank effluent. While the maximum septic tank influent BOD for onsite sewage systems is 220 milligrams per liter, Washington State guidelines suggest that recirculating sand filters may satisfactorily treat sewage with a BOD as high as 720 milligram per liter.

Calculate the loading rate (gallons per day per square foot) by dividing 1,150 by the BOD of the tank effluent. For residential applications the maximum loading rate is five gpd/sqft. If the BOD is suspected to be greater than 220 milligrams per liter, the loading rate will be lower. For repairs, alterations or expansions to existing systems or where BOD is suspected to exceed 220 milligrams per liter, composite sampling of the septic tank is recommended to generate good information. For new development, especially for nonresidential development, BOD should be estimated on the basis of the best available comparative information from similar facilities.

Determine the required surface area for the sand filter bed by dividing the average daily flow by the loading rate.

The depth of the bed will depend on whether gravel or a gravelless alternative is used. If gravel is used, the depth will be a minimum of nine inches if a one-inch diameter lateral is used. The bottom of the bed should be level. The minimum and optimum depth of the filter media is 24 inches. The bottom of the filter media should be level. Pea gravel depth is three inches. The underdrain gravel depth is a minimum of six inches with gravity underdrain, and sufficient depth to provide adequate storage volume when using a pump well/vault to pump sand filter filtrate to the next component. The gravel depths may be greater to provide additional storage volume if filtrate will be pumped form the sand filter to the next system component.

Place an underdrain pipe in the underdrain gravel at the same level or an inch or two above the main floor of the sand filter. This pipe should be slotted four-inch ASTM 3034 pipe or stronger. The slots should not be directly against the liner. They should either be facing 12 o'clock or, if facing six o'clock, have a few inches of gravel under the pipe and slots.

Select the type of containment vessel to be used. This will affect whether the sand filter is above or below ground. See the above discussion of single-pass sand filters for more detailed information.

Select the underdrain methodology and how the effluent will be transmitted back to the recirculating/mixing tank. This will usually be done via a gravity flow from the filter, which means it is critical that the elevations of the filter drain and the recirculation tank are evaluated.

Distribution Network

When pressure distribution is needed. The recommended number of doses per day is 48. **(See Section E: Pressure Distribution and Pumping Systems.)**

Recirculating Tank

For residential systems, the minimum volume of the recirculating/mixing tank should be 100 percent to 150 percent of the estimated average daily flow. For other establishments, tank volume should be 100 percent of the estimated average daily flow.

Doses are primarily controlled by a timer. Floats are wired in parallel with the timer to control the pump during periods of excessive wastewater flow and/or in the event of timer malfunction. A timer should control the recirculating pump in continuous cycles of five minutes on and 25 minutes off. Each unit of effluent is designed to flow through the sand filter about five times before it flows to the disposal component. This results in a recirculation rate of 5:1 (read as "five to one".)

Based on the 5:1 recirculation rate, determine the through-filter flow: the actual volume of effluent going through the filter each day:

daily design flow (gpd) x 5.

Next, determine the dose, in gallons per cycle:

through-filter flow (gpd) ÷ 48 cycles/day.

Once you know the dose, you can determine the pumping rate in gallons per minute:

gal/cycle ÷ 5 minutes/cycle.

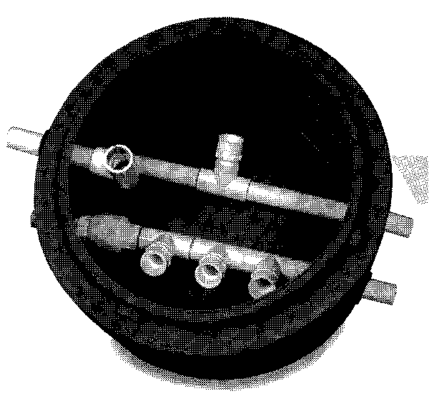
(See Section F: Pumping Systems for more information about selecting pumps.)

The recirculating pump should be located at the opposite end of the tank from both the inflow from the septic tank (or other pretreatment process) and the return from the filter. The pipe from the filter back into the recirculating/mixing tank is typically four inches in diameter. For larger flows, larger diameter pipe may be needed.

Recirculating Device

A buoyant-ball check valve. The elevation of this valve (typically 80 percent of the liquid depth) will control whether sand filter effluent flows back into the recirculating/mixing tank or out to the drainfield/discharge point. The ball must be sufficiently buoyant that it makes a good seal. The Valve requires the final discharge to be determined by the elevation of the pump station. The filter is dosed periodically by a timer. The periodic dose is continuous so filter resting is less, and maintenance events may increase but the quality potential is enhanced due to the filter being continuously active. The following picture was furnished by American Manufacturing.

Another type of splitter device is a distribution box or something similar like this Zabel basin assembly. Water flows in and fills the box. There are 3 openings in the return pipe to the recirculating tank and 1 opening to the discharge point. This allows 75 % of the flow to be returned to the tank and discharges 25% at all times. On this type of system there needs to be a shut off switch in the recirculating tank otherwise the pump tank will run out of water. The filter rests



during low flow so filter runs may be longer but the quality may be detracted from during restart after long rest periods.

There are other types of splitters on the market in addition to these shown above.

Placement

Flexibility in terms of siting is probably the single biggest advantage of a sand filter system. Because the filter is watertight and uses a medium for treatment, the soil on which or in which it is constructed is not critical. What is critical is the ability of the system to transfer oxygen, because without adequate oxygen, bacterial action will be seriously compromised. Wisconsin recommends using landscaping rock from the sand filter surface to the soil surface to maximize gas exchange. The location is entiled to avoid any excessive surface runoff being introduced into the system.

Soil and site conditions for sand filters are usually not critical. The primary consideration is that the site where the filter will be located needs to be stable. Additionally, care must be exercised to insure that seasonal high water tables or surface water does not enter the top of the sand filter. Soil and site conditions are critical for the disposal component following the sand filter.

Final Dispersal of Wastewater

This system will discharge very clean effluent, but the effluent must still be disposed of. Surface discharge is permitted in Iowa and is most commonly used. If the treated wastewater is disposed of into the soil then pressure distribution to the soil system is necessary, rather than gravity distribution, since the effluent from sand filters contains very little organic matter. Because the effluent is so “clean,” a biomat layer does not form as it does in soil treatment systems receiving effluent from septic tanks. A biomat layer makes the soil less permeable to water, so effluent flows through the length of the trench. Without a biomat, effluent tends to percolate through the soil only at the beginning of the trench, unless pressure distribution is used to apply effluent evenly throughout the soil treatment system.

Maximize the ability of the design and site to disperse wastewater and take in a minimum of groundwater and surface runoff:

- Making the soil dispersal area for a sand filter as long and narrow as possible.
- Minimizing the number of laterals down slope from each other.
- Running the laterals of the soil dispersal area so they are parallel with the slope contours.

The problem of dispersal becomes more difficult as the soil becomes shallower and finer-textured, and as the design flows become greater.

A crested site where subsurface flow can occur in multiple directions is desirable for soil dispersal areas. Look for areas with convex slopes, rather then concave slopes. Try to locate soil dispersal area on the upper part of a slope, rather than at the bottom of a slope. Stay away from drainageways, depressions or areas subject to flooding.

Strictly observing setback requirements and paying special attention to downslope geologic or soil conditions and land use activities will help mitigate problems with using systems on small lots. As the density of onsite sewage systems increases, especially on sites with shallow soils (frequently the case with intermittent sand filter systems) and where they are placed down-gradient from each other, concerns become greater. Especially on small lots, site evaluation should include assessment of the impacts that surrounding lot developments may have on the design and performance of a system.

Dispersal of Effluent from a Single-Pass Filter

Effluent from a single-pass sand filter may be surface discharged, flow to a drainfield or a mound. If a drainfield is used, a minimum vertical separation of 24 inches is recommended. You should design with additional separation to allow for groundwater mounding after the soil has begun to receive effluent.

Dispersal of Effluent from a Recirculating Filter

The receiving soil treatment system is designed using normal design methods and loading rates. No increase in loading rates is permitted with recirculating sand filter effluent. For either gravity or pressure distribution drainfields, it is recommended that the receiving drainfield must have a minimum vertical separation of 24 inches.

Advantages & Disadvantages of Mounds and Sand Filters

As the design professional decides which system and system components are the most appropriate for a given site, it may be helpful to quickly compare the different systems and components discussed in this course. Information on mound systems is included to help design and regulatory professionals understand the similarities and differences of mound and sand filter systems.

Mound

- Mounds may take up less area than a system of trenches.
- There is a continuous unsaturated flow from sand into original soil.
- Mounds use the upper horizons of soil, which are typically more permeable and contain more organic material.

but

- Mounds can create aesthetic problems and concerns.

- They can be seriously affected if multiple systems are downslope from each other.
- Site preparation and installation are critical.
- Materials may be costly.

Single-Pass Sand Filter

- Takes up relatively little area compared to mounds.
- Works well in conjunction with mounds to provide additional treatment on sensitive sites.

but

- Concrete or synthetic membrane liners can be costly.
- Repair or replacement work for a system with a liner must be done by hand.
- Two pumps are required: one to dose the sand filter, one to dose the soil dispersal area.

Recirculating Sand Filter

- Suitable for light commercial applications, treating tank effluent with a BOD of 230 to 720 milligrams per liter.
- Generally smaller in size than intermittent sand filters.

but

- Surface must remain open to encourage oxygenation.
- Requires more pumps and controls than intermittent sand filters.
- Concrete or synthetic membrane liners can be costly.
- Repair or replacement work for a system with a liner must be done by hand.

Management, Operation and Maintenance of Sand Filters

The local health agency has the authority to require that an acceptable maintenance agreement be established, and supporting documents be developed and approved by the local health official, prior to the issuance of approvals for a proposed sand filter sewage system.

Construction Plan

An important part of the design package is the construction plan. It contains specific instruction to the installer to help assure a quality installation. In addition to the step-by-step installation instruction, it should include the following:

- Routes for construction vehicles.
- Identification of reserve area and instructions to stay away from it.
- Instructions as to when the system can be constructed (time of year, moisture content).
- Instructions for proper grading, diking, ditching, and subsurface drainage.
- Instruction for fencing the disposal component and reserve areas if they are located in areas where vehicular, livestock, or pedestrian traffic could cause problems.
- Instruction for cleaning.

Maintenance

For the onsite treatment and disposal system to operate properly, its various components need periodic inspection and maintenance. The maintenance is the responsibility of the homeowner, but may be best performed by experienced and qualified service providers. Provide the owner with a description of maintenance concerns.

1. Type of use: describe the organic waste strength concerns and testing protocols.
2. Age of system: describe concerns about pump calibration and parts that may need replacement due to wear.
3. Nuisance factors: describe possible factors, such as odors or user complaints.
4. Septic tank: inspect yearly for structural integrity, proper baffling, screen, ground water intrusion, and proper sizing. Inspect and clean effluent baffle screen and also pump tank as needed.
5. Dosing and recirculating/mixing tanks: rinse the effluent screen (spray with hose), inspect and clean the pump switches and floats yearly. Pump the accumulated sludge from the bottom of the chambers,

whenever the septic tank is pumped, or every three years, which ever is sooner.

6. Pumpwell: inspect for infiltration, structural problems, and improper sizing. Check for pump or siphon malfunctions, including problems related to dosing volume, pressurization, breakdown, clogging, burnout, or cycling. Pump the accumulated sludge from the bottom of the pumpwell, whenever the septic tank is pumped, or every three years, whichever is sooner.
7. Check monitoring ports for ponding.
8. Inspect and test yearly for malfunction of electrical equipment such as timers, counters, control boxes, pump switches, floats, alarm system or other electrical components, and repair as needed. System checks should include improper setting or failure, of electrical, mechanical, or manual switches.
9. Pump and pump screen: inspect yearly and clean as needed.
10. Mechanical malfunctions (other than those affecting sewage pumps) including problems with valves, or other mechanical plumbing components.
11. Malfunction of electrical equipment (other than pump switches) such as timers, counters, control boxes, or other electrical components.
12. Material fatigue, failure, corrosion problems, or use of improper materials, as related to construction or structural design.
13. Neglect or improper use, such as loading beyond the design rate, poor maintenance, or excessive weed growth.
14. Installation problems, such as improper location or failure to follow design.
15. Septic tank maintenance, including pumping frequency, structural integrity, improper baffling, ground water intrusion, or improper sizing.
16. Overflow or backup problems where sewage is involved.
17. Exposed-surface filter bed: weed and remove debris from the bed surface, quarterly.
18. Specific chemical/biological indicators, such as BOD, TSS, and/or fecal coliform bacteria sampling and testing, may be required by the local health authority.

Owner's Manual

The design package will also include the owner's operation manual, which should include specific instructions to the system owner or their monitoring person. The owner's manual should contain:

- Diagrams of the system components and their location.
- Explanation of general system function, operational expectations, and owner responsibilities.
- Specifications of all electrical and mechanical components installed (occasionally components other than those specified on the plans are used).
- Names and telephone numbers of the system designer, local health authority, component manufacturer, supplier/installer, and the management entity to be contacted in the event of a failure.
- Information on the periodic maintenance requirements of the sewage system: septic tank, dosing and recirculating/mixing tanks, sand filter unit, pumps, switches, alarms, and disposal unit.
- Information on troubleshooting operational problems. This information should be detailed and complete to assist the system owner in making accurate decisions about when and how to attempt corrections of operational problems, and when to call for professional assistance.
- Information on the final landscaping of the site, including limitation about future plantings, and identification of activities that can't occur around the system and reserve area.
- Maintenance, monitoring and sampling requirements / recommendations. This includes inspecting monitoring ports, looking for leaking plumbing fixtures and tanks, and evidence of site protection. This should include forms and methodologies to be used.
- Description of the quantity and quality loading limitations of the system.
- For proprietary sand filter devices, a complete maintenance and operation document should be developed and provided by the manufacturer and made available to the system owner. A copy of this document should also be provided to the local health authority, prior to the issuance of the local installation permit.

Part III: Peat Filters

The following information is on a new product, peat filters. At the time of this publication this product was not listed in Chapter 69, therefore each County will need to determine the suitability of this product.

A peat filter is a treatment system in which septic tank effluent is applied to a approximately two-foot thick layer of sphagnum peat. Peat is an organic material made up of partially decomposed plants. It has a high water-holding capacity, large surface area, and chemical properties that make it very effective in treating wastewater. Unsterilized peat is also home to a number of microorganisms, including bacteria and fungi. All of these characteristics work together to make peat a very reactive and effective filter.

In some studies, peat filters have removed high concentrations of nutrients, BOD, suspended solids, and fecal coliform bacteria. In Minnesota, research peat filters have consistently done an excellent job of treating a wide range of waste strengths and waste types.

How Peat Filters Work

A peat filter has three parts: the distribution system, the peat itself, where the removal of organic matter and pathogens takes place, and the drain.

There are a number of different designs from peat filter suppliers. Some designs use peat in the form of loss peat replaceable bales, and gravity distribution seems to be effective with these products.

Filters using a pressure distribution system have been shown to be long lasting and provide good treatment of wastewater, however

The second part of the filter is the peat. The peat layer should be approximately two to two-and-one-half feet deep. Most of the peat used in manufactured systems comes from Canada or Ireland. It is harvested from large natural beds, then screened for the right consistency. Bord na Mona[1] brand filters use a peat from Ireland that is somewhat coarser. Systems using this coarser medium also provide excellent treatment. Systems using local peat or peat from landscape firms have failed in a short period of time and are not recommended.

The third part of a peat filter is the drainage system, consisting of a liner or tank to hold the effluent inside the filter, drainfield rock, and four-inch PVC pipe. The drainage system collects the effluent and delivers it to the dispersal area.

In some cases, the soil treatment system is different from those used to treat effluent from other pretreatment methods. Some companies, have developed a linerless or “bottomless” drain system, in which the effluent from the peat is allowed to drain directly into the soil below. In Iowa, the top of the soil below the peat filter system must have the three-foot separation from saturated soil, bedrock, or confining layer as required in Chapter 69. Sizing of a soil treatment area under the peat filter has not been full researched and is left up to the manufacture. However the effluent is highly treated and loading rate increases are appropriate.

Additional maintenance is required for peat filters**.** All the routine operation and maintenance practices suggested for any onsite treatment system apply to peat filters. In addition, because of the high organic content of the peat itself, maintenance includes periodically replacing the filter media. This means physically removing the layer of peat when it has begun to decompose. Life expectancy of the peat in a filter is estimated to be 8 to 15 years. The rest of the system, including pumps, distribution system, and liner, should last much longer, so system designs should facilitate easy removal and replacement of the peat. One development in system design is the peat “pod.” These pods are modular units of peat that are easily removed and installed.

Because of the unique treatment abilities of peat filters they are an alternative solution for some of Iowa’s wastewater treatment needs.

The following fact sheets are supplied by peat filter manufactures and are included for informational purposes only. This manual makes no recommendation on any manufactures product.

The Ecoflo® Biofilter

The unit consist of a small fiberglass shell containing a patented sphagnum peat moss filtering media (Fig.1).

Wastewater from the septic tank flows into the Ecoflo® Biofilter and is evenly distributed over the surface of the peat using a unique distribution system with no electrical requirements.

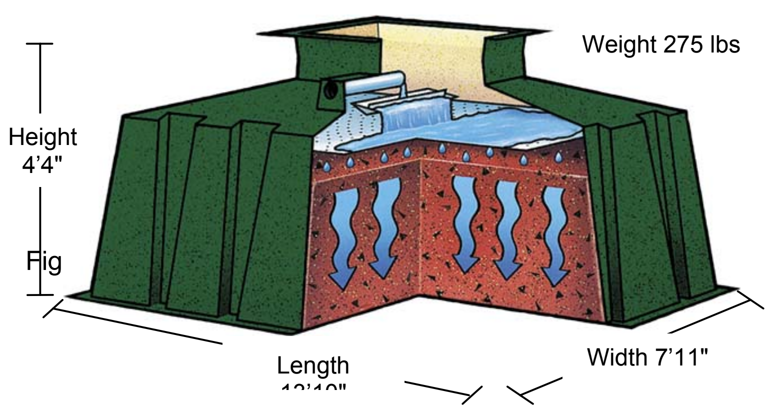
The wastewater is treated as it percolates down through the peat, and the effluent is then disposed for infiltration into the native soil or discharged to a watercourse in accordance with existing local regulations.

Treatment Efficiency

Parameters	Percentage of treatment by the Ecoflo® Biofilter	Septic Tank Effluent	Ecoflo® ST-650 Biofilter Effluent
Biochemical Oxygen Demand **(BOD_5)**	95%	≤ 250 mg/L	≤ 10 mg/L
Total Suspended Solids **(TSS)**	90%	≤ 75 mg/L	≤ 10 mg/L
Fecal Coliforms **(CFU/100 ml)**	99%	≤ 2 000 000 CFU/100 ml*	≤ 25 000 CFU/100 ml*

* Geometric means correspond to ≤ 750 000 CFU/100 ml at septic tank outlet and to 2 000 CFU/100 ml at Ecoflo® Biofilter outlet.

The Ecoflo® Biofilter Treatment

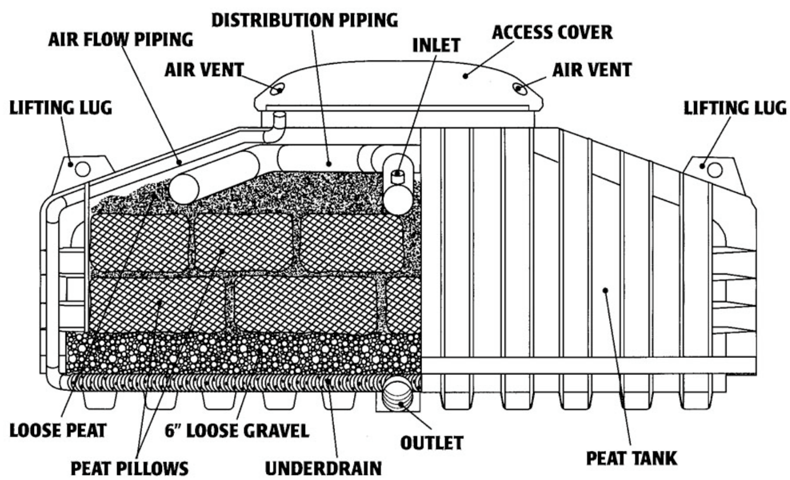


Premier Tech Environment
6021, Terrace Hills Dr. Birmingham, AL
35242, USA
Tel.: (205) 408-9691 Fax: (205) 408-8783
E-mail: ecoflo@premiertech.com
Website: premiertech.com
Toll Free Number: 1-877-295-5763

ECO-PURE WASTEWATER SYSTEM

- A passive secondary advanced treatment system.
- Influent enters the system from the septic tank and moves into the distribution piping.
- Effluent is distributed through the peat to the bottom of the tank where it enters into the underdrain.
- The effluent exits through the outlet and moves to the absorption area.
- A 5-year maintenance agreement is included with each system.
- An annual inspection under the maintenance agreement consists of: cleaning the septic tank filter and inspecting the peat filter, hose out the distribution piping and rake peat if necessary.

ECO~PURE PEAT BIOFILTER

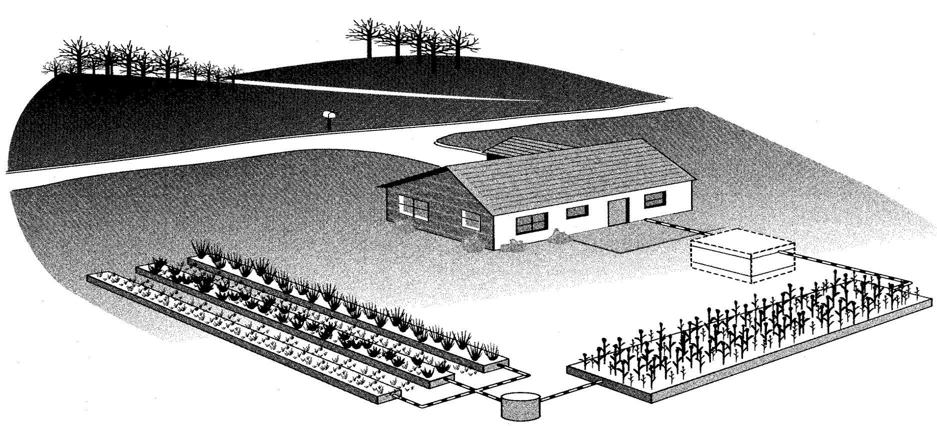


PART IV: CONSTRUCTED WETLANDS

A constructed wetland system treats wastewater by filtering, settling and bacterial decomposition in a large natural-looking marsh. As wastewater moves through the constructed wetland system, the solids are removed through physical filtering and settling. The organic matter is broken down by bacteria, both aerobically, with the oxygen supplied by the plants growing in the wetland, and anaerobically, whenever there is little or no dissolved oxygen in the water. These systems have been used in the U.S. and elsewhere with mixed results.

The constructed wetland system is made up of three parts: the liner, the distribution medium, and the plants. The liner keeps the wastewater in the system and excludes groundwater. Although the liner can be made from a number of materials, 30 mil PVC is the most common and probably the most reliable. Clay liners, which have recently been the subject of interest, can crack, allowing the wastewater to move into the soil and contaminate groundwater. For this reason, clay liners are not recommended.

The distribution medium at the inlet is usually pea gravel. This first part of the distribution system feeds the wastewater to the wetland, spreading wastewater across its width. Both gravity and pressure distribution can achieve even spreading of the wastewater over the system, allowing the water to flow evenly through the length of the system. The next portion of the distribution system is the rock media where the plants, usually cattails, but sometimes including sedges, grow. The last part is the polishing filter/sand filter before discharging the water into the environment.



System Designs

Three wetland designs are common: open water, hydroponic, and subsurface flow. **Subsurface flow systems** are the type required by Chapter 69 for use in Iowa. Open water systems look like ponds. Wetland plants grow from the bottom and the water moves through the system at the surface. Because the water is fairly deep, the surface area required for this design is the smallest. Water evaporates off the surface and oxygen from the air gets dissolved in the water, so bacteria can break down the waste aerobically. Unwanted plants and animals, including insects, can take up residence in an open-water constructed wetland.

A new EPA manual “Constructed Wetlands Treatment of Municipal Wastewaters” EPA/625/R-99/010 may provide more detailed information. Check the EPA web site at www.epa.gov.

Subsurface flow systems are the type recommended for use in Iowa. They are constructed so all effluent moves through a medium (rock) with the plants growing in the medium. All the wastewater flow occurs below the surface of the media and does not pond on the surface. Because there is no free water surface, there is no danger of the system freezing in winter. These systems typically require more space than open water systems, but less space than hydroponic systems.

Treatment processes are both aerobic, with oxygen being supplied by plant root systems, and anaerobic at microsites within the pea rock media where there is no dissolved oxygen. The anaerobic decomposition reduces nitrogen levels in the discharge. This double action also allows for excellent removal of bacteria and phosphorus, if adequate time is provided for wastewater to move through the system. Roughly 6 days of detention time is recommended to adequately treat waste with the typical strength from a residence.

Hydroponic systems are shallow, with most of the water flowing in the root zone of the plants. In these systems, as in open water systems, water evaporates off the surface and there’s plenty of oxygen available, in addition to what the plants produce. The plants tend to take up nutrients from the water more efficiently than in open water systems. These systems are very shallow, however, so they have to be much larger than open water designs, and they are more likely to freeze in winter. Fencing to prevent human contact with wastewater is essential in these systems as well.

Sizing

The size of the system is typically based on the wastewater remaining in the wetland for 6 days. For subsurface flow systems, the space occupied by the rock medium must be included in calculations for the system size; a 40 percent porosity ratio takes the rock volume into account, increasing the system volume necessary for adequate retention time. Chapter 69 requires 300 square feet per bedroom when using common septic rock. The shape is not critical except that it should prevent wastewater from flowing too quickly through the system. The typical shape is rectangular with a length-to-width ratio of 10:1 to 20:1 is recommended. Chapter 69 recommends 33:1, based on the recent EPA manual this may be long. The other system components are sized using typical engineering practices and pipe flow characteristics.

Placement

The system is designed to run level, so the system should be located on the contour. Surface water inflow can cause overloading problems, so drainage should be directed away from the system. A barrier to soil erosion into the wetland, such as rock landscaping or sod, is needed to minimize sediment problems. Berm around the wetland keep surface water out. Variations in shape may be used to fit site.

Final Dispersal of Wastewater

Wastewater from the constructed wetland system may be discharged on the surface. Chapter 69 requires a polishing filter before discharge to the surface.

Operation and Maintenance

Water levels must be maintained. The proper functioning of the constructed wetland system is dependent on water being in it at all times. Periods without flow may allow the system to dry up, killing the plants and bacteria that treat the waste. During vacation periods make sure the system has adequate water supplies in the summer and winter. Plant and bacterial life processes are critical to the operation of the system. Large flows may also lead to inadequate treatment, by washing pathogens and nutrients right through. These large flows may be caused by excessive wastewater flows or by natural events such as torrential rains. These can lead to a long-term reduction in the ability of the system to provide treatment.

Influent quality can affect the system. Toxic chemicals can harm or kill plants and bacteria in the wetland. In commercial applications, plugging of the media with excess solids, undercomposed organic matter, or grease may be a concern; however, this problem has not been researched.

The septic tank must be routinely inspected and pumped, see section C.

Inspect the plants for signs of stress, excessive dead material, yellowing and insects. Check the water level. Check with a local garden center for help in identifying the problem and solution.

Keep the water level 3 to 4 inches below the surface at all times.

Winter Operation

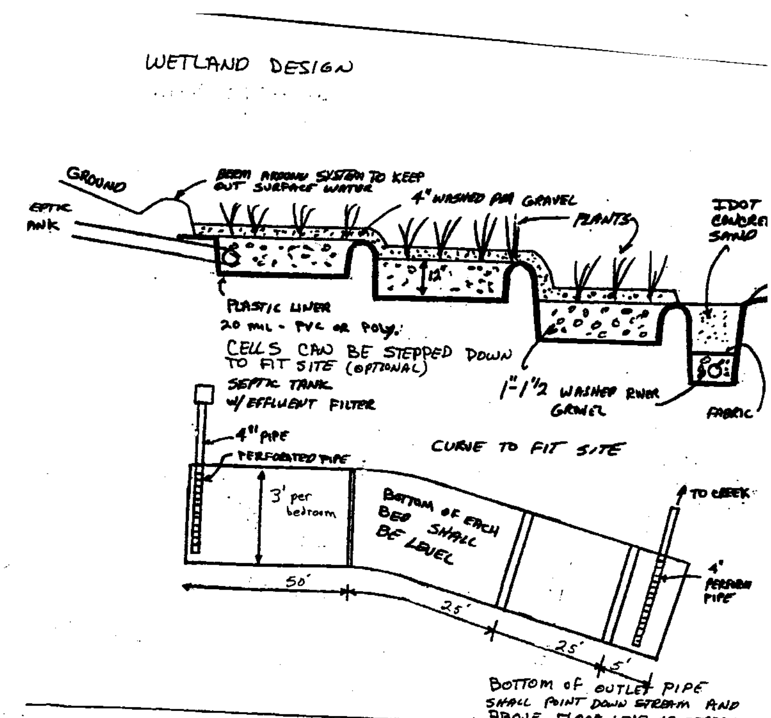
In the late fall cut the plants and cover the rock and sand filter with 3 to 4 inches. If there is not enough plant material use hay or straw. Do not use plastic sheeting this may reduce the oxygen flow and allow the system to go septic. In the spring remove the dead material from the rock.

Typical System Design and Layout

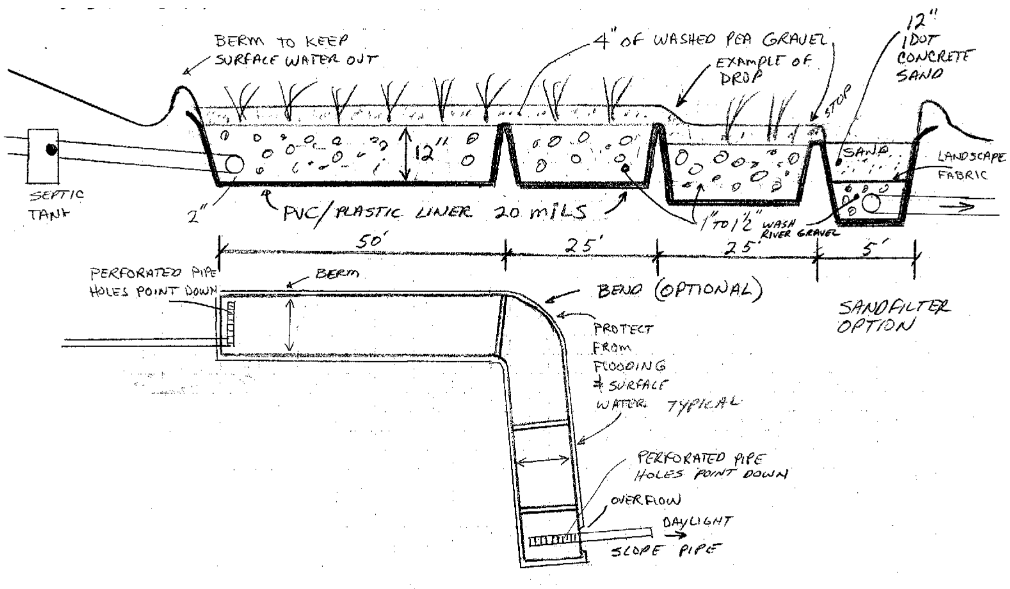
Subsurface flow system, assume 1-bedroom system, this can be increased for number of bedrooms.

Flow 150 gallons per day	
Length = 50 feet	Alternate Length = 100 feet
Width = 6 feet	Alternate Width = 3 feet
Number of cells = 3	3 cells
#1 = 25 feet	#1 = 50 feet
#2 = 15 feet	#2 = 25 feet
#3 = 15 feet	#3 = 25 feet

Depth of water and 1-inch rock = 12-inches
Depth of cover rock, pea gravel = 4-inches
Plants at 12-inches on-center



NOTES:
1. Layout is for concept, fit to site.
2. Bottom of each bed shall be level.
3. Minimum bed sizes shown.
4. Provide berm around entire wetland to keep surface water out.
5. Plants: collect plants in the area, leave mud ball on roots.
   Use common cattail, narrow leaf cattail, bullrush, and reeds.
   Plant at – foot on center.
   Cut plants down each fall, to insulate bed in winter, remove in spring.
6. Check sand often, and rake clean.



Plants

The plants are the visual indicator of the wastewater treatment system and should include several different kinds to add interest to the system. The best time to plant is in the spring of the year but they may be planted up to August. Plants need time to establish their root system to survive the winter. Water must also be available to the plants.

Plants must be adapted to the climate conditions of the system therefore it is recommended that the plants be collected locally for best results. Four common types of plants are:

Common Cattail - Typha Latifolia

Narrow Leaf Cattail - Typha Angustifolia

Bullrush - Scirpus Americanus

Reed - Phragmites Communis

There are many other types of species available including flowering plants such as irises and lilies which may add variety and color to the treatment system, however, do not grow food for consumption in the wastewater system.

If the plants are collected locally, a small amount of soil should be left on the root ball to help establish the plant. The plants should be spaced no more than 12-inches on center. Fertilizer is not needed if the system is to be used immediately.

PART V: MECHANICAL AEROBIC AND OTHER SYSTEMS

The following paper was reprinted with permission from James C. Converse.

IOWWA thanks James for all of the support and information provided.

AERATION TREATMENT OF DOMESTIC WASTEWATER FOR ON-SITE TREATMENT OF DOMESTIC WASTES

AEROBIC UNITS AND PACKED BED FILTERS

James C. Converse[1]
January, 1997
Revised, January 1999
Revised, February 2000

On-site waste treatment and management utilizes anaerobic and/or aerobic processes for the treatment of domestic waste. A number of units are commercially available and can be categorized as either **aerobic units (ATUs) or packed bed filters (PBFs)**. Aerobic units are submerged units in which air (oxygen) is introduced into the mixed liquor with oxygen diffusing into the liquid. Pumps and blowers provide the air. Packed bed filters are unsaturated units in which the air diffuses in and through the voids created between the media. Air diffuses in from the atmosphere. Some units will have a small fan to increase circulation of the air.

This publication is divided into two main categories: aerobic units and packed bed filters. All units approved in Wisconsin as of January, 2000 will be described. It will also contain other units. **This presentation is not inclusive and does not imply endorsement of one product over another and it will continually be updated to include more units.**

TESTING PROTOCOL

To establish quality control in aerobic units (ATUs) and protect the public from poor quality and low performance units, NSF, International, in cooperation with the industry and the regulatory community, developed a testing performance standard (Standard Number 40), (NSF, 1996). For a fee, NSF, International will test aeration units using domestic waste under a controlled pilot plant (field) environment measuring influent and effluent quality and performance under various loading regimes. The standard has Class I and Class II levels based on performance standards as follows:

---

[1] James C. Converse, P.E., Professor, Department of Biological Systems Engineering, College of Agricultural and Life Sciences, University of Wisconsin-Madison. Member of the Small Scale Waste Management Project.

Note: Names of products and equipment mentioned in this publication are for illustrative purposes and do not constitute an endorsement, explicitly or implicitly. It does not include all units available on the market and the presence or absence of a product does not imply acceptance or rejection of a particular product.

Class I Effluent

Plants providing a Class I effluent shall be shown to meet EPA Secondary Treatment Guidelines (Federal Register, 1987) for BOD_5, SS, and pH. These are as follows:

$CBOD_5$:

- The 30-day average of $CBOD_5$ concentration of effluent samples shall not exceed 25 mg/L.

- The 7-day average of $CBOD_5$ concentration of effluent samples shall not exceed 40 mg/L

TSS:

- The 30-day average of TSS concentrations of effluent samples shall not exceed 30 mg/L.

- The 7-day average of TSS concentrations of effluent samples shall not exceed 45 mg/L.

pH:

- The pH of individual effluent samples shall be between 6.0 and 9.0.

Other:

- Color - 15 units
- Threshold Odor - non-offensive
- Oily Film - nonvisible evidence other than air bubbles
- Foam - None

Class II Effluent

Not more than 10% of the effluent $CBOD_5$ values shall exceed 60 mg/L. Not more than 10% of the effluent TSS values shall exceed 100 mg/L.

As noted, NSF, International primarily evaluates a unit for BOD and suspended solids effluent concentration. With the increased interest in nitrogen removal and pathogen removal, all aeration units should be evaluated for nitrogen and pathogen removal. For soil based treatment/dispersal, pathogen and nitrogen removal are as important if not more important than BOD and suspended solids removal. BOD and suspended solids removal have been and will continue to be important parameters, especially for surface water discharge and are used by the industry for secondary treatment performance. **Phosphorus and virus removal are also important emerging concerns**. To date no packed bed filters have been NSF tested. The fact that they have not been NSF tested should not imply that they are inferior or incapable of receiving NSF classification. In fact some aerobic units have not been NSF rated. Many reasons may dictate why a company has not had their unit evaluated. **Standard 40 was developed to evaluate aerobic units (ATUs).** Since then a number of packed bed units have emerged.

AEROBIC UNITS (ATUs)

Aeration technology, known as activated sludge, extended aeration and similar other names, is used extensively in large municipal systems for treating wastewater. Industry has developed "miniature" plants adapted for small clusters and for individual home use. This discussion will be limited to the concepts and performance of small units known as individual home wastewater treatment plants, aerobic units or ATUs and other units that utilize aeration for treating the wastewater that come as "prepackaged units". **These units can be categorized as either: 1) suspended growth , 2) attached growth (submerged fixed media) or 3) combination of both. Aeration is achieved by mechanically delivering air bubbles to a liquid (water) media where the oxygen diffuses into the liquid so it can be utilized by the bacteria.**

ATUs have been marketed for many years in some parts of the country but are now being introduced in other parts of the country. Many improvements have been and are continuing to be made and new systems are being introduced.

System Characteristics

- Systems can be either batch or flow-through (known as intermittent flow).

- Most systems have a septic tank/trash tank, external or internal, to settle out the large solids and scum. Some systems may pump the effluent from the septic tank to the aerobic unit utilizing a timer for more uniform loading. The septic tank must be water tight.

- All system have a method of incorporating air into the wastewater to maintain dissolved oxygen in the wastewater either continuously or intermittently.

- All systems incorporate some method of solids separation such as settling, filtering through a fabric or through a plate filter.

- All systems require sludge removal or destruction.

- Systems operate in an extended aeration mode to reduce solids accumulation except for periods when they are loaded heavily.

- Most units are quite sensitive and can be easily upset by the addition of toxic chemicals and some medications. Rapid and large changes in organic and hydraulic loading can upset these units. During these times the units may foam and froth with increased BOD and SS effluent concentrations. Seeding the unit at start-up and after upsets will usually bring the system to stability earlier.

- Excess solids may on occasion exit the unit either around the cover or through the effluent pipe (bulking) depending on system configuration. Bulking takes place when the solids do not settle out and as a result exit the unit through the outlet pipe.

- All systems have sensors and high water alarms to alert the owner to problems.

- Most units state power rating in horsepower or amps and volts and state the cfm and pounds of BOD_5/day that the unit is capable of processing. They also state flow rate in gpd they are capable of handling.

- All systems require periodic maintenance by a professional at 6 month intervals. Telemetry may reduce the frequency of site visits.

Suspended-growth Units

In suspended growth systems, microorganisms are kept in suspension in an aeration tank where air is mixed with the wastewater. The following systems primarily use suspended-growth as the method of converting organic matter into bacterial cells, carbon dioxide and water.

a. Multi-Flo Waste Treatment Unit

The unit is constructed of fiberglass and comes factory assembled (Fig. 1). This unit is NFS Class 1 rated. The unit comes in a variety of sizes with the smallest unit of 500 gallons capable of treating the effluent from a 3 bedroom home. Larger units, up to 1500 gallons, are available.

A trash tank, proceeding the unit, may or may not be recommended for removal of settleable solids. The wastewater (or trash tank effluent) enters the inlet and drops into the basin (activated sludge or mixed liquor portion). Flow is by gravity. Some systems are installed with a pump located in the trash tank with a timer which doses a small amount of wastewater frequently during the day to provide a more uniform flow into the unit (Fig. 2). Surge capacity is designed into the trash tank. Small. frequent doses are desired.

An aerator, located in the bottom of the tank, pulls in air and disperses fine bubbles which work their way to the top with oxygen dissolving into the effluent.

As wastewater enters, an equal amount of effluent moves through the filter fabric, upward inside the filters (cylinder) and over the weir, exiting through the outlet. The filter fabric retains the solids (primarily bacterial cells) within the basin. The filter surface acts as a fixed media for bacteria growth. The surge bowl allows for some foaming and surge capacity. Liquid sensors are located to detect high water and pump failure.

This unit removes some nitrogen but it does not incorporate a discrete nitrification/ denitrification phase as part of the treatment process. Access to the unit is through the cover and lifting out the surge bowl.

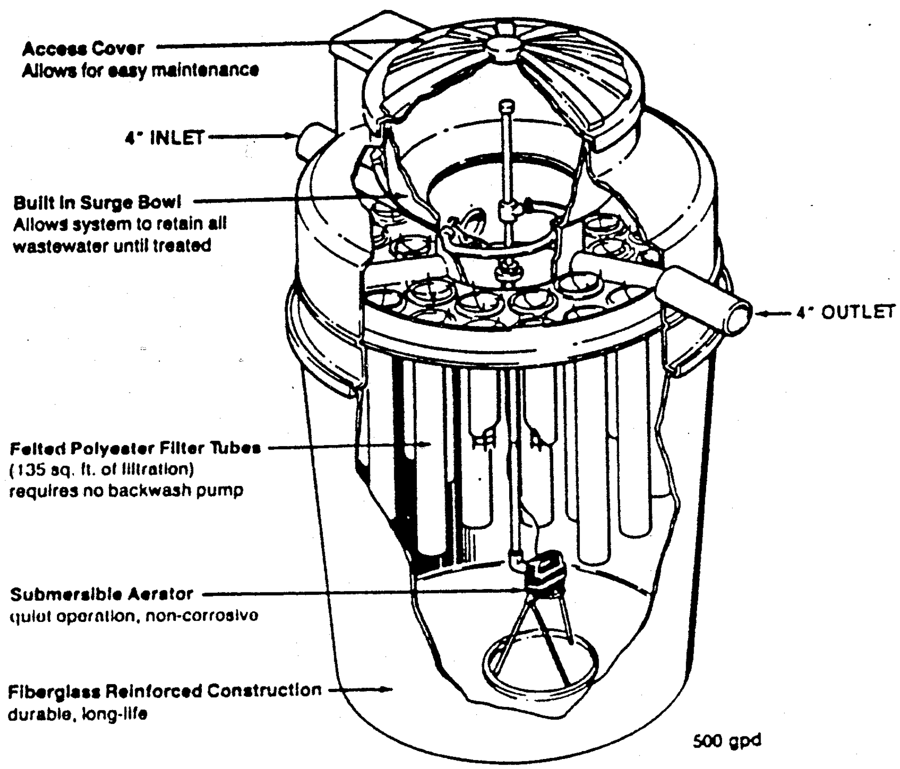


Fig. 1. A cut-away view of the Multi-Flo unit. (Consolidated)

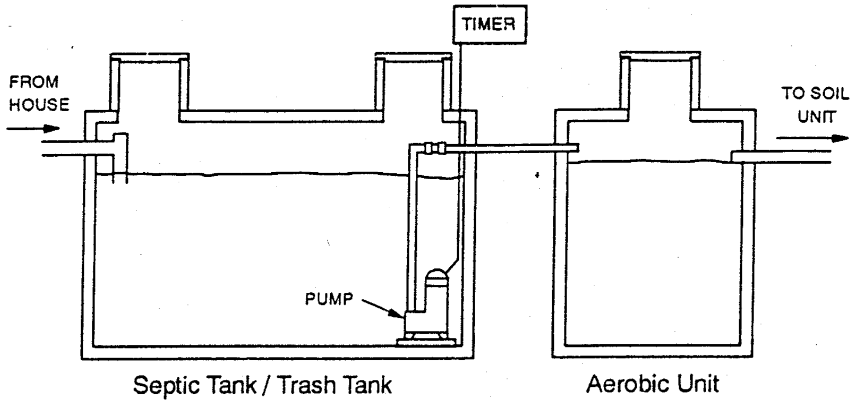


Fig. 2. Illustration of a trash/septic tank with pump and timer pumping effluent to the aeration unit minimizing surge flow.

b. Norweco Singulair Wastewater Treatment Plant

The unit consists of a concrete tank divided into 3 compartments (Fig. 3). The tanks are locally manufactured and outfitted with factory-made pumps, filters and controls. This unit is NSF Class 1 rated. The unit comes in several sizes with the smallest being a 500 gpd unit serving a 3 bedroom home.

The wastewater from the home enters a pretreatment chamber where the larger solids settle out. The liquid volume of the pretreatment chamber is approximately 440 gallons in the 500 gpd unit.

The effluent enters the extended aeration chamber through a submerged port where the suspended and dissolved solids are converted to bacterial cells, water and carbon dioxide. The contents of this chamber are typically called mixed liquor. The liquid volume of this chamber is 590 gallons for the 500 gpd unit.

A top-mounted motor rotates a shaft with a hub with several openings. Air is drawn through the hollow shaft and through the holes in the hub with bubbles dispersing into the mixed liquor. The rotating hub and air bubbles keep the contents mixed. Oxygen is diffused into the mixed liquor as the air bubbles move in the liquid.

Mixed liquor moves to the clarifier through a port located in the bottom of the unit. The solids settle to the bottom of the clarifier. The sloping walls of the clarifier assists the movement of solids back into the aeration chamber.

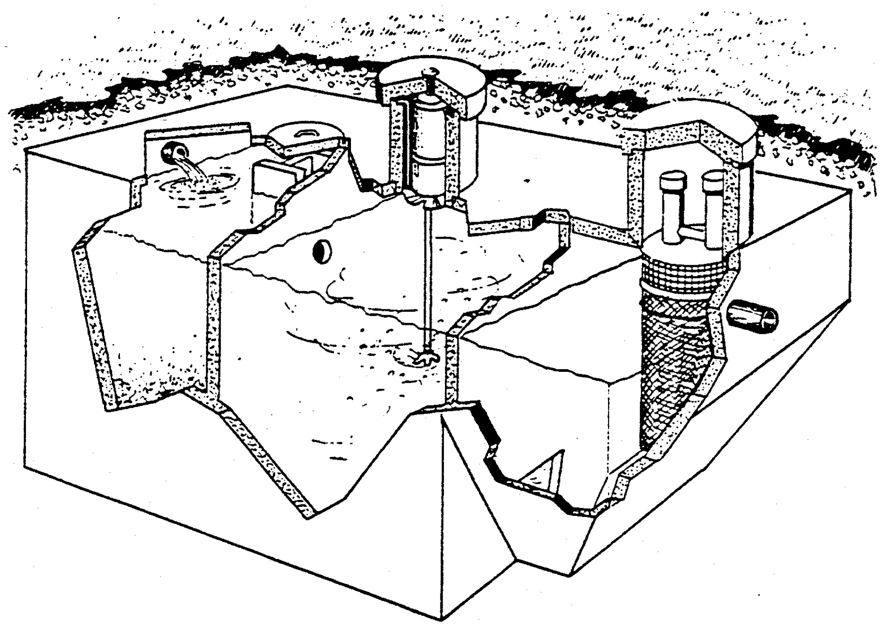


Fig. 3. Cut-away view of the Norweco Singulair unit (Norweco).

The effluent moves into the Bio-Kinetic filter unit which consists of a series of plates that promote quiescent settling. The remaining solids settle out and a relatively clear effluent exits the tank through the outlet. This unit removes some nitrogen but it does not incorporate a discrete nitrification/ denitrification phase as part of the treatment process.

Access to the system is through the inspection port (pretreatment chamber), the aerator port (aerator lifts out) and the Bio-Kinetic port (clarifier).

c. Cromoglass

The unit consists of a 3 compartment fiberglass tank (Fig. 4). This unit is classified as an sequence batch reactor (SBR) as it is a fill and draw (batch) unit. It comes in several sizes with the smallest unit serving a 3 bedroom home.

The wastewater from the home enters the solids retention section where the large solids settle out. Effluent enters the aeration chamber through a screen located in the wall, near the bottom, dividing the solids retention and aeration chamber.

The pump in the aeration section circulates mixed liquor in the aeration chamber and forces mixed liquor through the screen into the solids retention section breaking up the solids and also pumps it into the contact clarifier. The mixed liquor flows back into the aeration chamber via an opening in the wall near the top.

As the pump moves mixed liquor through the overhead pipe, air is pulled in through the air intake allowing oxygen to dissolve into the mixed liquor. The pump operates continuously mixing and aerating the mixed liquor.

At a preset time or when the mixed liquor reaches a certain level, the pump shuts off allowing the solids to settle in the clarifier for a 60 minute period. After settling, the effluent is pumped out of the clarifier. The timer is normally set for six aeration/settle/ discharge cycles per day. The discharge pump will not operate when the liquid level in the aeration chamber is below the low water float level. Thus, the number of discharges will depend on the flow to the system.

Some nitrogen is removed during the process. However, a denitrification option is available. This option requires the installation of the next larger size unit, a timer and controls to disengage the circulating pump, stopping aeration. The oxygen is rapidly depleted producing an anoxic condition in the aeration and clarifier sections resulting in the denitrification of the nitrates. After a prescribed time, the timer starts up the pump which provides oxygen to the unit.

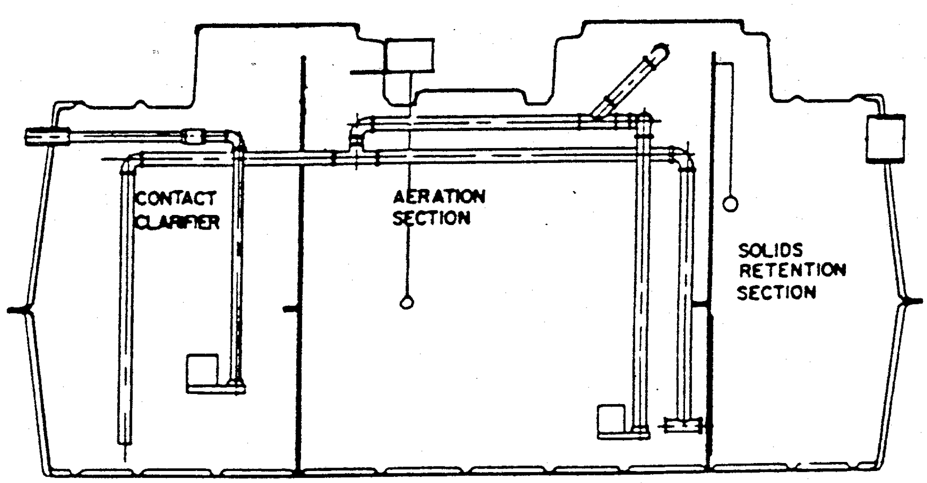


Fig. 4. Cross section of a Cromoglass unit (Cromoglass).

d. **Clearstream Wastewater Unit**

The unit consists of a single tank with a Imhoff cone in the center (Fig. 5). Unit sizes range from 500 to 1500 gallon capacity. This unit is NSF Class 1 rated. The household wastewater enters an external trash trap with a volume of 50 to 100% of the gallon per day rating of the Clearstream unit.

A remote blower supplies air to a diffuser located along the outside wall near the bottom of the tank. Influent enters the tank near the outer edge and moves down around the outside of the Imhoff cone where it comes in contact with the mixed liquor. Effluent moves up through the bottom of the Imhoff cone which provides a quiescent settling area for solids to fall back into the mixed liquor portion of the tank.

The effluent exits through a tertiary filter (optional) attached to the outlet pipe. Solids need to be removed from the tank periodically. This unit removes some nitrogen but it does not incorporate a discrete nitrification/ denitrification phase as part of the treatment process.

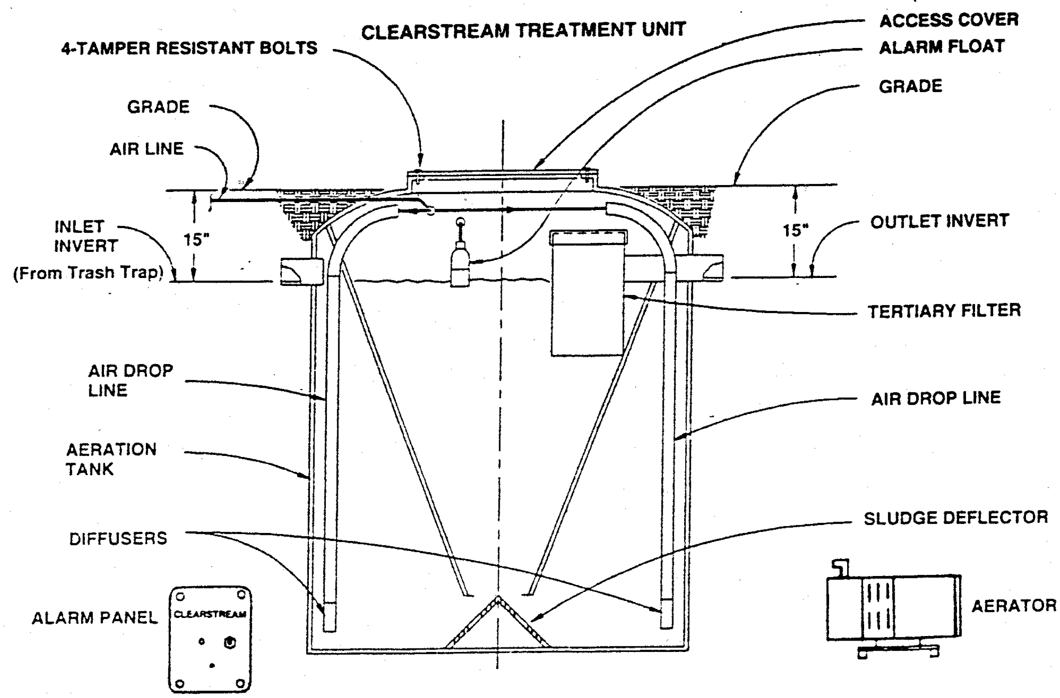


Fig. 5. Cross section of a Clearstream unit (Clearstream).

e. Delta Whitewater

The unit consists of a single tank with a Imhoff cone in the center (Fig. 6) in sizes ranging from 400 gpd to 1500 gpd. This unit is NSF Class 1 rated.

The household wastewater may or may not enter an external trash trap (optional).

A remote blower (65 watts) supplies air to several diffusers located along the outside wall near the bottom of the tank. A minimum of 2100 cf of aeration is provided per each pound of BOD_5. The 400 gpd unit has a treatment capacity of 1.0 lb BOD_5.

Influent enters the tank near the outer edge and moves down around the outside of the Imhoff cone where it comes in contact with the mixed liquor. Effluent moves up through the bottom of the Imhoff cone which provides a quiescent settling area for solids to fall back into the mixed liquor portion of the tank.

The effluent exits through the outlet pipe. Solids are removed from the tank periodically. This unit removes some nitrogen but it does not incorporate a discrete nitrification/ denitrification phase as part of the treatment process.

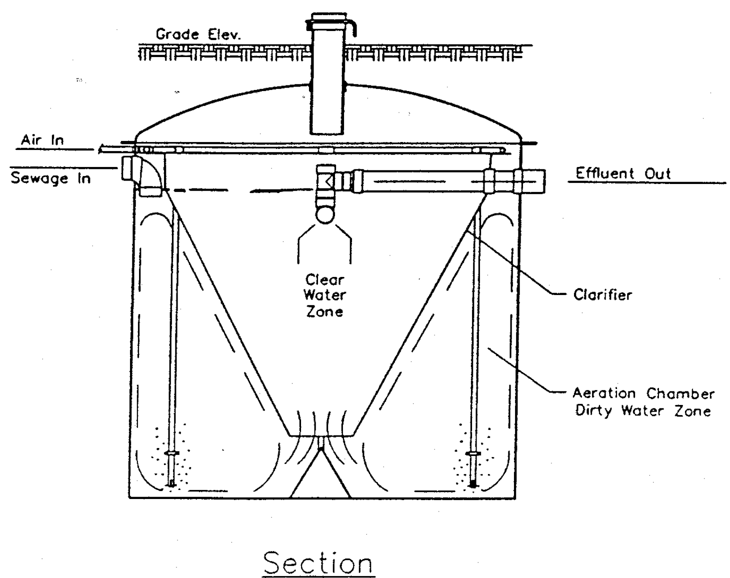


Fig. 6. Cross section of a Delta Whitewater unit (Delta).

f. Nayadic

This unit consists of a two concentric cone shaped tank with one compartment inside the other. Fig. 7 shows a cut-away view of the tank with sizes ranging from 500 to 1500 gpd capacity. This unit is NSF Class I rated.

The tank normally receives effluent directly from the source with a trash tank up front optional. However, for best performance time dosing with small frequent doses is recommended (Fig. 2) with a trash tank serving as a surge tank.

The raw wastewater enters the inner compartment. A blower discharges air to a diffuser in the open bottom of a draft tube in the center of the inner tank. The air lifts the mixed liquor upward with the solids settling down around the outside of the draft tube. The cycle continues with the aeration and mixed liquor confined to the inner tank.

As wastewater enters the tank, effluent from the inner tank moves downward through the solids laden mixed liquor in the bottom and upward in the outer tank. As the effluent rises, the solids settle downward to the center below the draft tube and are drawn up into

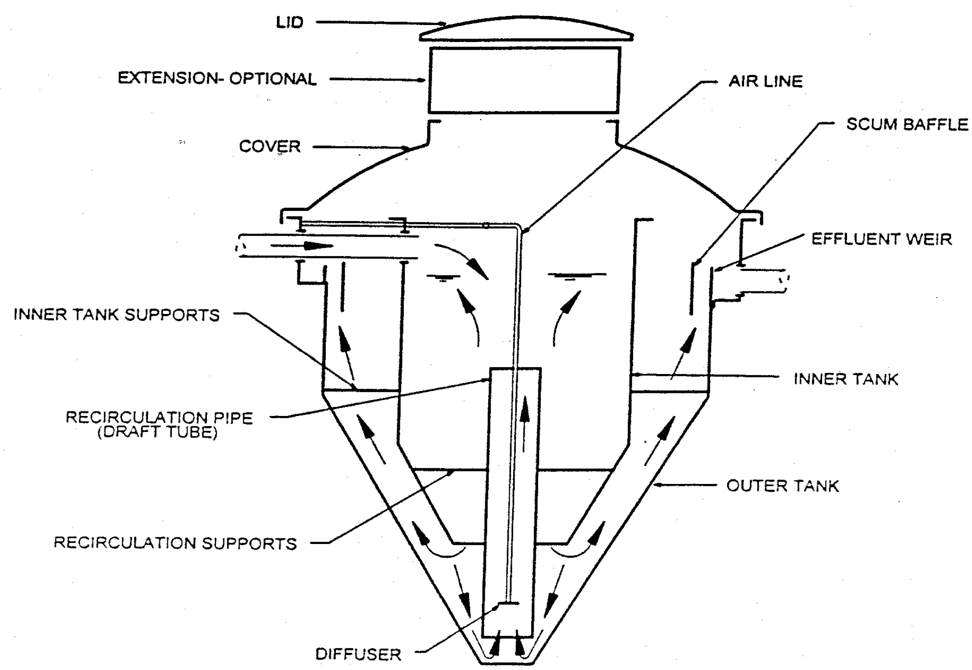


Fig. 7. A cut-away view of the Nayadic wastewater treatment unit (Consolidated).

the mixed liquor. Clear effluent flows over the 360° weir and out the exit pipe. A scum baffle located inside the overflow weir keeps floating solids from passing over the weir.

This unit removes some nitrogen but it does not incorporate a discrete nitrification/ denitrification phase as part of the treatment process. However, as the nitrified effluent moves downward into and through the solids laden bottom where the oxygen levels are probably very limited some nitrogen removal, via nitrification/denitrification, takes place.

Attached-growth Units

Attached-growth aerobic units incorporate a large surface area for bacteria to attach themselves. These surface areas may be fixed or they may be floating cylinders/spheres that move around in the mixed liquor.

a. Jet Treatment Plant

The J-353 model contains the "Jet Bat Process Media" in the aeration section (Fig. 8). This unit is primarily a submerged attached-growth media unit with the lower portion operating as suspended-growth phase. This unit is NSF Class 1 rated. It comes in several sizes.

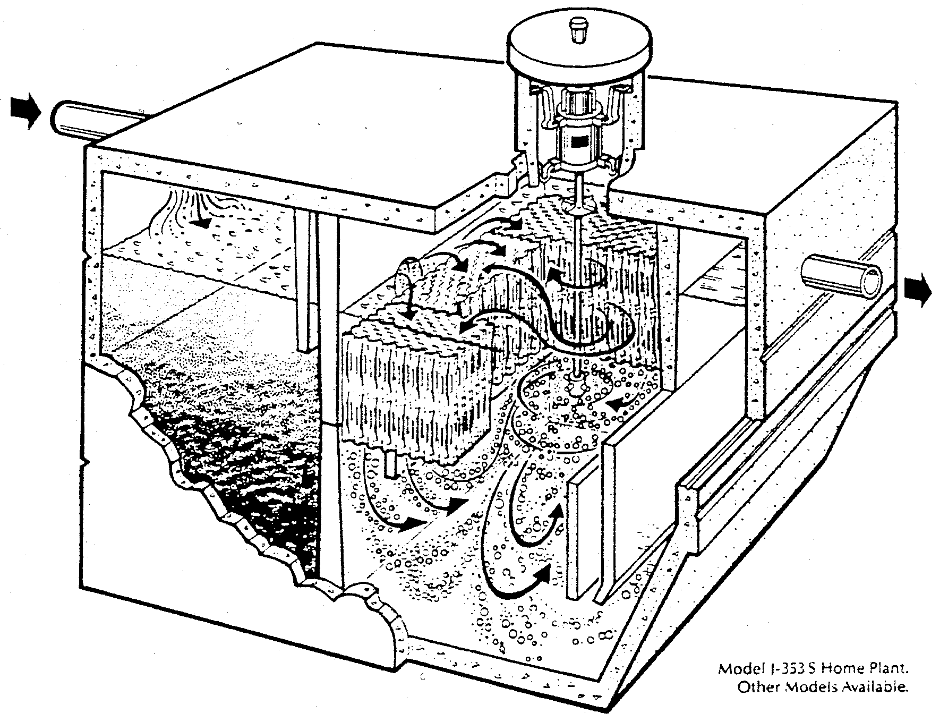


Fig. 8. A cut-away view of the J-353 Model Jet aeration plant for home use (Jet).

The wastewater from the home enters the pretreatment tank where the solids settle out. The chamber is sized at 475 gallons for a 3 bedroom size home. The effluent enters the extended aeration chamber through a submerged port where the suspended and dissolved solids are converted to bacterial cells, water and carbon dioxide. This compartment is sized at 600 gallons. Bacteria are attached to the fixed media in the upper portion of the compartment.

A top mounted motor rotates a shaft with a hub containing several openings. Air is drawn through the hollow shaft and through the hub with bubbles dispersing into the mixed liquor surrounding the shaft. Oxygen is diffused into the mixed liquor as the air bubbles move in the liquid. The rotating hub and air bubbles circulates mixed liquor throughout the fixed media. The mixed liquor moves through the porous media supplying dissolved oxygen and food (Fig. 8). Solids slough off the fixed media settling to the bottom of the compartment.

The mixed liquor moves out the bottom of the aeration chamber into and up through the clarifier section where the solids settle out. Some of the solids move back into the aeration chamber with the assistance of the sloping wall. This compartment is sized at 125 gallons. An optional tube settler is available for this compartment. The effluent flows out through the outlet pipe.

b. Bio-Microbics - FAST

This unit consists of a two compartment tank (Fig. 9). The tanks are locally manufactured and outfitted with a media chamber, external blower and controls. It has a NSF Class 1 rating.

Solids settle out in the first compartment with effluent flowing into the second compartment through a hole located near the top of the wall.

The FAST media chamber, inserted into the top of the second compartment, provides large surface area for bacteria attachment. The bottom of the chamber is open. An air lift tube (tube within a tube) is located in the center of the fixed media. Air, from an external blower is forced downward in the inner tube. As it exits the inner tube, it flows upward between the larger and smaller tubes. The air bubbles lift mixed liquor upward dispersing it over the top of the media where the mixed liquor and dissolved oxygen move downward through the media. Bacteria extract the organic matter, converting it to carbon dioxide, water and new cells. Organic nitrogen and ammonia are converted to nitrates. Solids slough off the fixed media and accumulate in the bottom portion of the second chamber.

A small trough located on top of the media (not shown) diverts some of the mixed liquor through the chamber sidewall into the second compartment outside the aeration chamber, where anoxic conditions exist. The nitrate is denitrified to nitrogen gas.

As wastewater moves into the second compartment, liquid moves out the discharge pipe which is connected to the inner chamber. Access to each compartment is through risers (not shown). Solids are pumped from both chambers, periodically. A nitrification/ denitrification process is designed into this system.

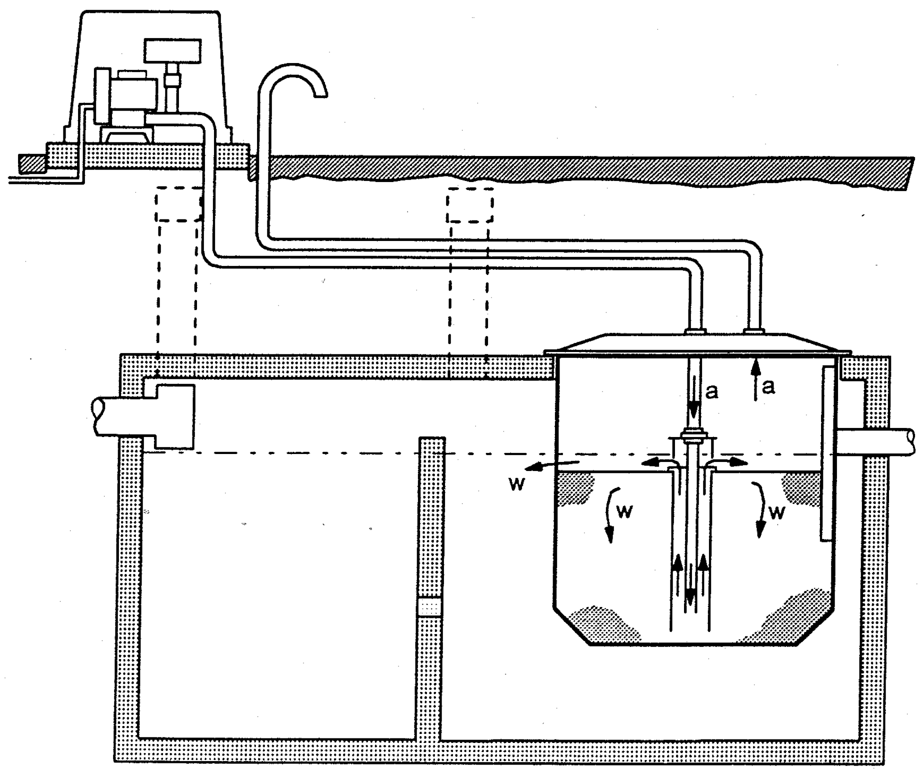


Fig. 9. Cross section of a Bio-Microbics FAST unit (Bio-Microbics).

c. MicrosepTec EnviroServer

The unit consists of a 5 compartment tank along with a thermal processor, blower(s), chlorinator and computer. This unit has an NSF Class 1 rating. It has been evaluated by the University of California - Riverside and has several accreditations by ANSI , SCC and RvD. Fig. 10 shows a cut-away view of the unit. The units come in 600, 1200 and 1500 gpd size.

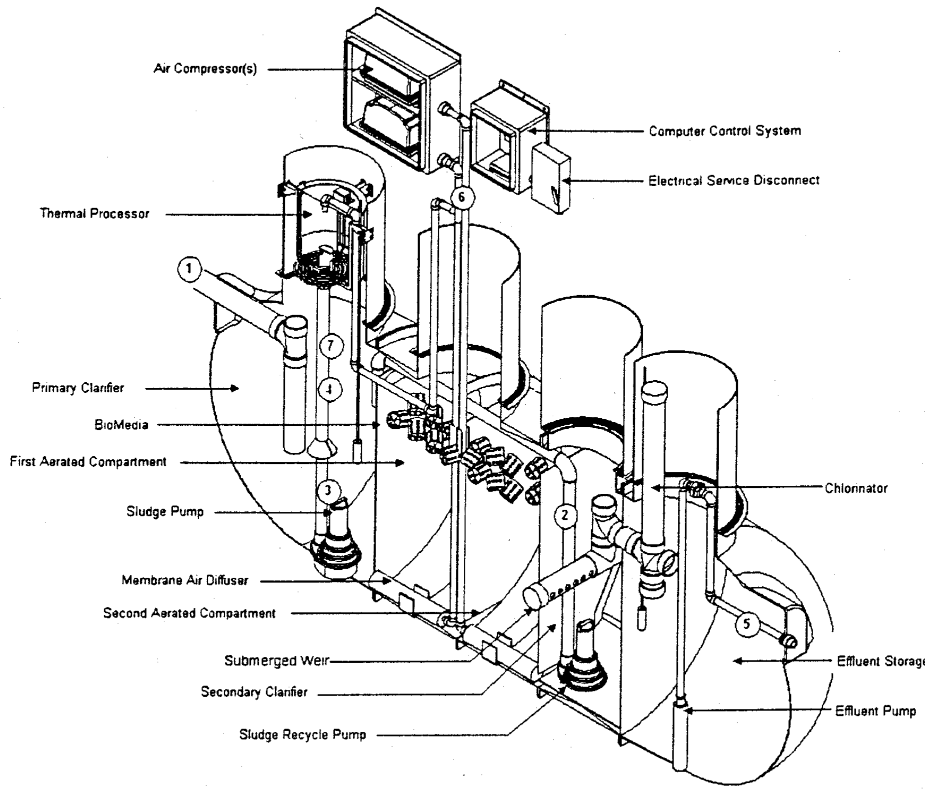


Fig. 10. Cut-away view of the EnvironServer Wastewater Treatment Unit (MicrosepTec).

The wastewater enters the primary clarifier where solids settle and the effluent and scum flow to the first aerated compartment with effluent movement into the second aeration compartment. Both of these compartments have floating media consisting of small cylinders with fins which serve as attachment sites for the bacteria. Air is delivered via a compressor and membrane air diffuser dedicated to each compartment. The small cylinders move around in the mixed liquor. There is about 15 cu. ft. of biomedia in each compartment for the 600 gpd unit. A single blower serves both compartments in the 600 gpd unit. The organic matter and suspended solids are reduced and the ammonia is converted to nitrate.

The mixed liquor flows through a submerged weir to the secondary clarifier chamber (compartment 4) where solids are settled out. A pump recycles the settled solids and effluent back to the primary clarifier where the nitrates are denitrified. In the 600 gpd unit approximately 50 gph is recycled to the primary chamber with the pump controlled by a timer.

Effluent flows from the secondary clarifier through a chlorinator into the effluent storage unit where a pump discharges it from the unit.

A sludge pump, located in the primary clarifier and controlled by a timer, discharges accumulated solids, controlled by a timer, to a thermal processor where the effluent flows via gravity through a screen (1/16" opening) back into the primary clarifier. The screen retains solids. When the solids accumulate to a prescribed depth, the thermal processor reduces the solids to ash and gas using a 220 volt electric burner. The ash falls into the primary clarifier and the gas is scrubbed as it exits the processor.

A computer monitors the process and is connected to the Microseptec headquarters for 24 hr monitoring. Monitoring includes primary and secondary alarms, high water level, air compressor (pressure switch), disinfection (ORP sensor), thermal decomposition cycle (thermocouples) and sludge pump (temperature change). Regulators, via password, can access the monitoring.

c. The Nibbler and Nibbler Jr.

Nibbler: The Nibbler was developed to reduce the high strength wastes (restaurant and other) to BOD levels of typical residential septic tank effluent (Fig. 11). The high strength wastewater (grey water, not black waters) enters a septic tank/ grease trap before entering the Nibbler.

The Nibbler consists of a concrete tank with pods of buoyant media in the upper portion of the tank. The media serve as attachment surfaces for the bacteria. A settling zone exists in the lower portion of the tank. Air is introduced in the lower portion of the pods with the mixed liquor circulated through the media. A small blower located adjacent to the unit supplies the air.

The upper portion of the mixed liquor is aerobic while the lower portion is anaerobic. Facultative bacteria, operating under either aerobic or anaerobic conditions, exist in an intermediate zone. Treated effluent with lower BOD, TSS and FOG (fats, oils and greases) exits the unit.

Nibbler Jr.: The Nibbler Jr. was developed for residential use (Fig. 12) to renovate failing soil absorption units by significantly reducing the organic load to the failing system. The unit is designed to remove BOD and suspended solids but not to the same extent as expected of Class 1 units. The unit is placed in the second compartment of a double compartment tank. It is desired to have the opening in the clear zone between the tanks for the first compartment can provide surge capacity. The liquid level in both tanks moves up and down through out the day as wastewater enters the first compartment and the effluent is slowly discharged from the system. The unit can be placed in a second tank but must have sufficient surge capacity.

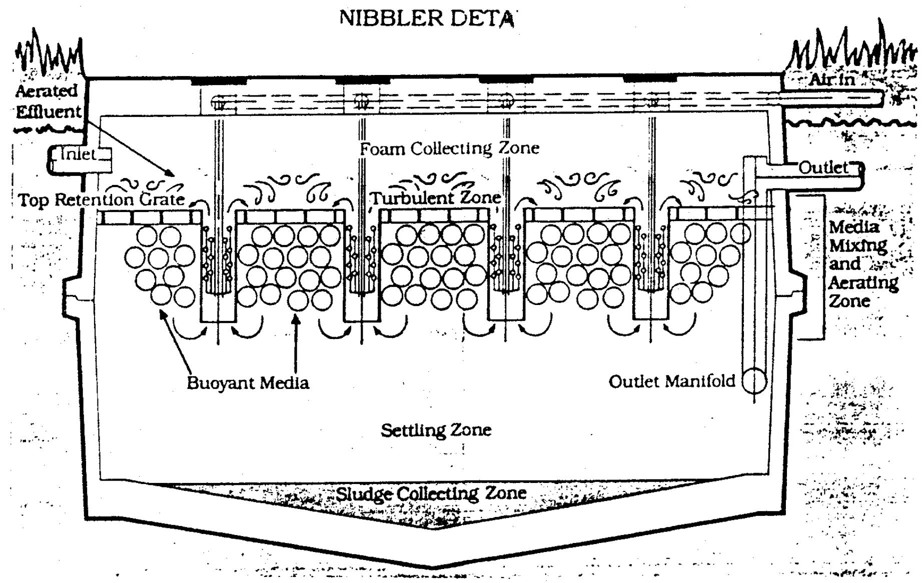


Fig. 11. The Nibbler for high strength wastes. (NCS)

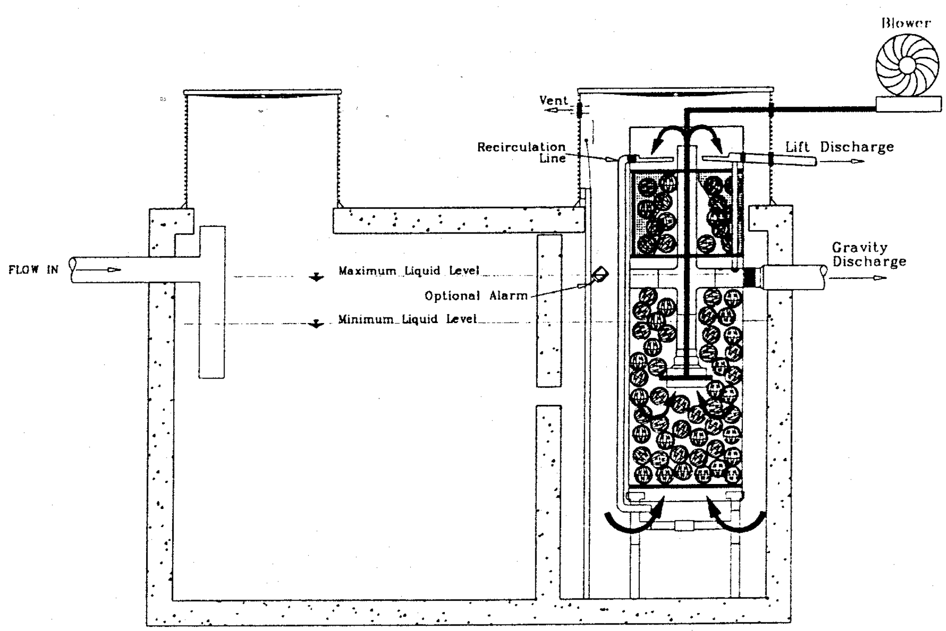


Fig. 12. Nibbler Jr. is placed in the second compartment of a two compartment tank. Effluent can discharge by gravity or be lifted (NCS).

Air is introduced near the bottom of the unit via an air lift tube using a regenerative blower located adjacent to the unit. The air lifts the wastewater upward between the inner and outer tube with a portion of the wastewater recycled to the bottom of the unit and a portion exiting the tank. The portion recycled and exiting the unit can be adjusted by changing the collection surface area, located in the splash zone.

This unit removes some nitrogen. Nitrogen reduction is enhanced by recycling a portion of the effluent to the bottom of the unit provided nitrates are present. This unit was not designed to specifically remove nitrogen.

d. Rotating Biological Contactor

A septic tank upstream removes the settleable solids. Effluent enters through the submerged inlet from an upstream septic tank (Fig. 13).

The disks rotate slowly with a portion of the disk submerged in the septic tank effluent. The biological growth is attached to the disks. During the submerged portion of the cycle, the bacteria come in contact with the organic matter in the effluent and during the air exposed portion of the cycle, oxygen diffuses into the biological mat maintaining aerobic conditions.

Biological growth slough off the disks into the unit with solids recycled to the septic tank or removed from the unit. Pumping of solids is required periodically. Some nitrification/denitrification is likely in this process.

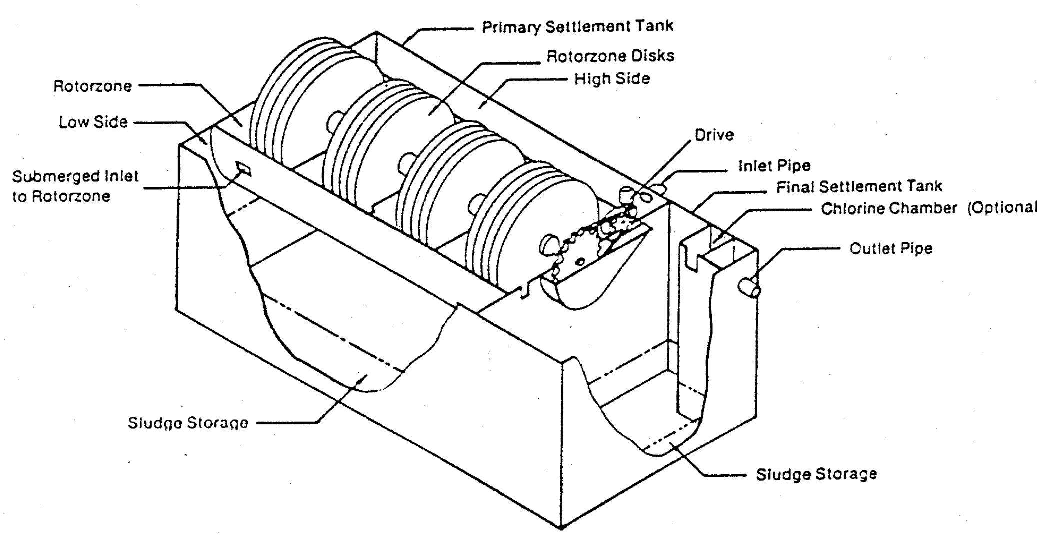


Fig. 13. Schematic of a rotating biological contactor (CSM Rotodisk Inc.)

PACKED BED FILTERS (PBFs)

Packed bed filters, are also known as fixed film media units and trickling filters. The most popular packed bed filter, known primarily as an intermittent sand filter, dates back to the late 1800s where it was used to treat wastewater. Single pass sand filters and recirculating sand/gravel filters have been used for many years. More recently, peat filters and synthetic media filters have been developed. These units can operate as single pass filters (sand and peat) or as multiple pass (recirculating) filters. Aeration is achieved by air diffusing through the open voids in the media with oxygen diffusing into the cell mass attached to the media. Some units will use a small fan to assist air movement in and around the media. Bacteria and other microflora attach themselves to the media. As the wastewater trickles downward over the media, the bacteria extract the organic matter and utilize the dissolved oxygen from the wastewater.

System Characteristics

- Systems are either single or multiple pass (recirculation).
- All systems have a septic tank to settle out the large solids and scum.
- Oxygen is supplied via atmospheric diffusion into the voids between the media. Some units use a small fan to assist aeration.
- Bacteria attach themselves to the media.
- Physical, chemical and biological reactions take place as the effluent moves over the media and through some of the media (foam and textile). Solids are filtered out, organic matter is converted to carbon dioxide and water with new bacterial cells being generated but not to the same extent as in some aerobic units. Nitrogen is converted to nitrate.
- For the most part, packed bed filters are more tolerant, some more so than others, to upsets by overloading and toxic materials entering the units. However, they can be upset if some care is not exercised.
- Most systems are operated with timed dosing which requires some controls and surge capacity in the septic tank/pump chamber. Some systems allow gravity flow to the unit.
- All systems should have sensor and alarms especially if pumps are part of the system.
- The septic tank needs to be monitored for solids and scum accumulation and pumped when appropriate. Solids accumulation in the packed beds generally does not accumulate as rapidly as in aerobic units. Units, loaded very heavily, will accumulate solids more so than units less heavily loaded.

- In single pass filters, nitrogen is converted to nitrates with some denitrification taking place on micro sites that are anoxic. In recirculating filters, all or a portion of the filter effluent is recycled to a recirculating tank that receives septic tank effluent or back through the septic tank. Some type of flow splitter diverts part of the effluent downstream for further processing or dispersal. Denitrification takes place in the recirculating tank if the anoxic conditions exist. Denitrification is enhanced if the filter effluent is recycled to the septic tank.

- These units need periodic maintenance by a professional. Some units may need monitoring every 6 months while others may require monitoring annually. Telemetry may reduce the number of site visits and will provide continuous monitoring.

Parts of page 20 and all of pages 21-29 were not reprinted

c. Waterloo Biofilter

The Waterloo Biofilter is a fixed media aeration unit consisting of a septic tank, pump chamber and biofilter placed in a wooden building above ground or in a concrete container with cover below grade (Fig. 22).

Media consists of 2" foam plastic cubes (same material as used in seat cushions) placed at random in a pod. The pod consists of a cylinder basket made of semi-rigid netting material that is about 2 ft in diameter by 2 ft high. The pods are stacked two high. A spray nozzle is located directly above each set of pods with effluent time dosed to the nozzle. A fine mist is applied over the entire top of the pod. Bacteria grow on the surface and inside the foam cubes. As the effluent moves downward, the effluent flows over the foam and into the foam cubes.

Air moves through and around the cubes to provide oxygen to the bacteria. A fan is mounted in the side of the unit to assist in air movement. The effluent exiting the unit flows to flow splitter where a portion of the effluent flows to the soil dispersal unit with the remainder flowing back to the septic tank or the pump chamber where denitrification takes place.

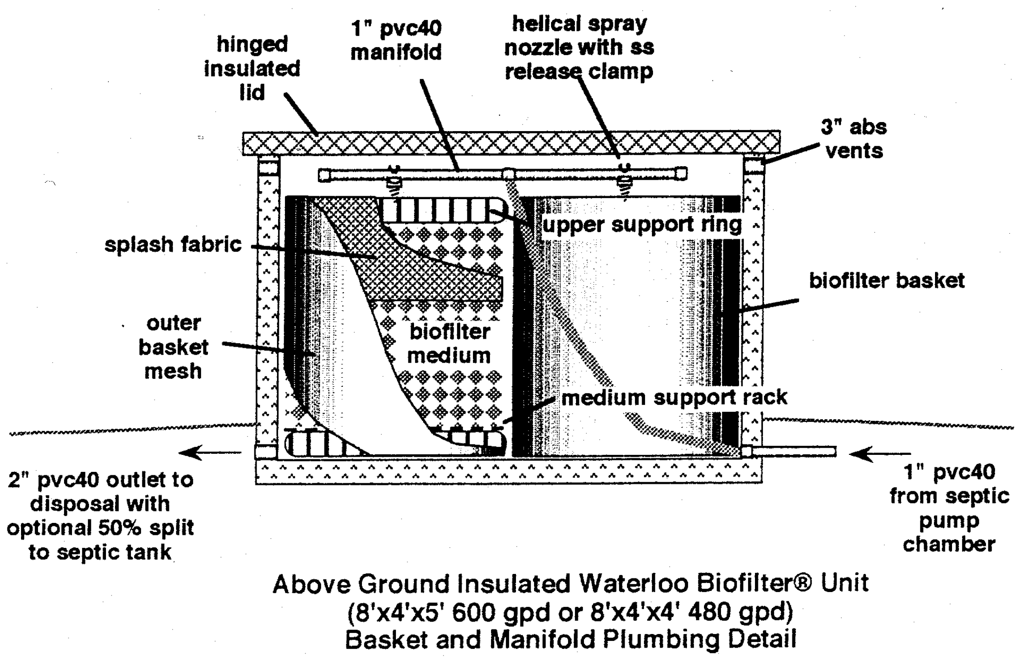


Fig. 22. Waterloo biofilter for on-site treating of wastewater. The system can also be installed below ground surface (Waterloo Biofilter Systems Inc.).

d. Aerocell Advanced Modular Treatment System

The Aerocell Advanced Modular Treatment System consists of a septic tank, pump chamber, aerocell treatment modules and a flow splitter (Fig. 23). It utilizes open-cell plastic foam as the treatment medium which is the same media as used in the Waterloo Biofilter. The unit comes in modules consisting of a plastic tank approximately 30" in diameter and 30" high. Four and 6 modules in parallel are required for a 3 and 4 bedroom homes, respectively. The filtered septic tank effluent is pumped to each pod where the effluent is sprayed on the surface.

The effluent passes over and through the media where the bacteria consume the organic matter and the nitrogen is converted to nitrate. The filter effluent passes to a flow splitter where a portion is recycled to the septic tank for denitrification and the remaining portion flows to a pump chamber or drain field.

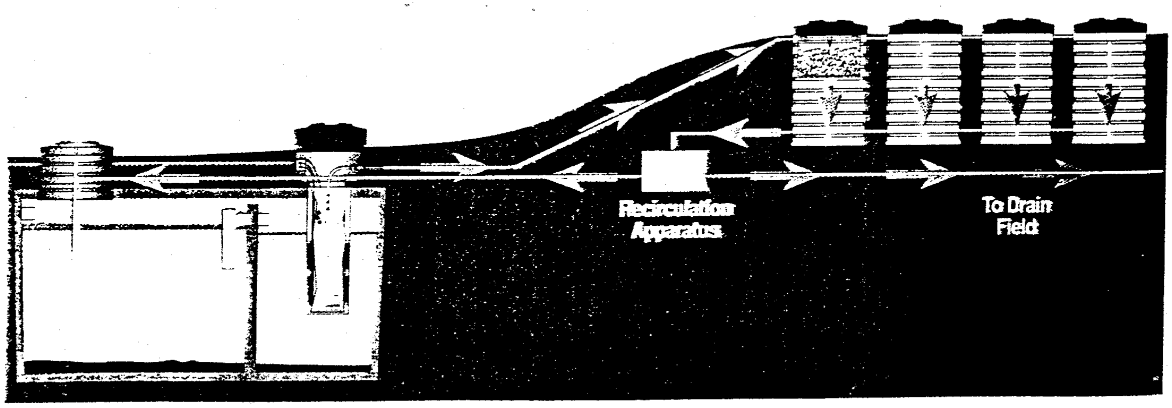


Fig. 23. View of a Aerocell advanced modular treatment unit (Zabel).

e. Bioclere System

This system incorporates a septic tank upstream of the Bioclere unit (Fig. 24). This unit is NSF Class 1 rated and comes in 500 gpd capacity and larger units.

The septic tank effluent passes into the baffled zone in the sump of the unit. The effluent is pumped at timed intervals to the top of the trickling filter where it is distributed over the filter media. The media consists of randomly packed plastic media serving as attachment sites for the bacteria. As the wastewater passes over the media, the bacteria remove the organic material and convert the nitrogen to nitrates. Air diffuses into the media void area to provide aerobic conditions in the filter. A fan assists in the air movement.

The effluent reenters the sump where it is mixes with the sump contents. A portion of the effluent is recycled through the trickling filter, depending on the amount of septic effluent entering the unit. The solids that slough off the trickling filter settle out in the bottom of the sump. The nitrate is denitrified. Clarified effluent exits the unit through the discharge pipe.

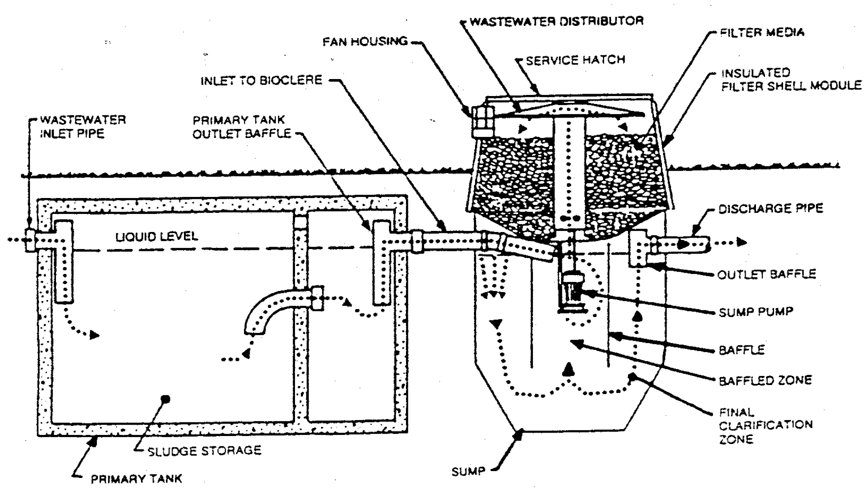


Fig. 24. Cross section of a typical residential Bioclere system (Ekofinn Limited).

e. Others

There are many other aeration type devices on the market that serve in the same capacity as those listed above. It is not the intent of the author to discriminate against any one by not including their unit. More units will be added as time permits.

REFERENCES

Federal Register. 1987. U.S. Congress, Washington, DC

NSF. 1996. Standard Number 40. Individual aerobic wastewater treatment plants. NSF International.3475 Plymouth Road, P.O. Box 1468, Ann Arbor, MI 48106. (313-769-8010)

Converse, J.C.. 1999a. Single pass sand filters for on-site treatment of domestic wastes. Small Scale Waste Management Project. 345 King Hall, University of Wisconsin-Madison. 608-265-6595. Http://www.wisc.edu/sswmp.

Converse, J.C.. 1999a. Recirculating sand/gravel filters for on-site treatment of domestic wastes. Small Scale Waste Management Project. 345 King Hall, University of Wisconsin-Madison. 608-265-6595. Http://www.wisc.edu/sswmp.

LIST OF MANUFACTURERS REFERENCED IN TEXT

Bio-Microbics Inc., 8271 Melrose Drive, Lenexa, KS. 66214 (913-492-0707)

Clearstream Wastewater Systems, Inc. P.O. Box 705, Silsbee, TX 77656 (409-385-1395)

Consolidated Treatment Systems Inc. 1501 Commerce Center Drive, Franklin, OH. 45005 513-746-2727.

Crest Precast Inc. 609 Kistler Drive, LaCrescent, MN 55947. 1-877-843-4231. www.RIGHTSystem.com

Cromaglass Corporation, P.O. Box 3215, Williamsport, PA 17701, (717-326-3396)

CMS Rotodisk Inc. 5266 General Rd. Unit 12, Mississauga, Ont. Canada L4W 1Z7.

Delta Environmental Products Inc. 8275 Florida Blvd, Denham Springs, LA 70727. (800-219-9183)

Ekofinn Limited, 33639 Ninth Ave. So. Federal Way, WA 98003 (206-661-6128)

Jet Inc., 750 Alpha Drive, Cleveland, OH 44143 (216-461-2000)

NCS, 16207 Meridian, P.O. Box 73399, Puyallup, WA (206-838-2359)

Norweco, Inc. 220 Republic Street, Norwalk, OH 44857-1196 (419-668-4471)

Orenco Systems Inc. 814 Airway Avenue, Sutherlin, Oregon. 97479-9012. (1-800-348-9843). Www.orenco.com

Waterloo Biofilter Systems Inc. 2 Taggart Court, Unit # 4 Guelph, Ontario, N1H 6H8, Canada. (519-836-3380)

Zabel Environmental Technology, 10409 Watterson Tr. Louisville, KY40299-3701. (1-800-221-5742). Http://www.zabel.com.

ASSESSING PERFORMANCE OF ON-SITE TREATMENT UNITS THAT TREAT THE WASTEWATER AEROBICALLY

James C. Converse[1]
January, 2000
Revised: Sept., 2000
Revised: Feb., 2001

How does one assess if the on-site wastewater treatment unit, utilizing aerobic principles is performing adequately? These units include aerobic units, single pass sand filters, recirculating sand filters, peat filters, constructed wetlands, biofilters and other units that treat the wastewater aerobically. In order to assess if a unit is performing satisfactory and to its design potential, the evaluator must understand the goals of the unit. For example, is the goal of the unit to treat the effluent to a high degree (BOD and TSS < 25 mg/L and Fecals to <10,000 col/100 mL) or is it to reduce the organic load to the downstream unit and not necessarily reduce the BOD to < 25 mg/L etc.

A. Sampling: In order to assess the performance , one needs to sample the effluent. There are basically two types of sample which are:

1. **Grab sample** - sample taken from the unit which will provide information on performance at the time the sample was taken. Sample taken from the end of the pipe are typically grab samples.

2. **Composite sample** - sample taken at intervals over a period of time, normally 24 hours. The various sub-samples are mixed together to form a "composite" sample. Size of individual sub-samples are normally proportional to flow quantity. This process requires installation of a special instrument called "composite sampler" or similar name. It usually requires preserving the sample during the collection process.

3. **Pump chamber sample** - the pump chamber serves as a "compositor" of the effluent. Taking a grab sample from the pump chamber provides a composite sample.

[1]James C. Converse, Professor, Biological Systems Engineering, University of Wisconsin-Madison. 460 Henry Mall, Madison, WI 53706. jcconver@facstaff.wisc.edu. Member of Small Scale Waste Management Project.

When reporting results, the sampling location and type of sample should be reported.

B. Analysis/Evaluation

Performance analysis is done at the site and samples sent to the laboratory.

1. **On-site analysis:** This will include examining the physical performance of the actual unit and the effluent sample.

a. Physical performance - Examine if the following items are functioning:

1. Air blowers or pumps, connections and filters
2. Pumps
3. Alarms
4. Filters
5. Mixed liquor sample for aerobic units (suspended growth). This is done by taking a grab sample of the contents, putting it in a graduated cylinder and observing the level of solids. If setteable solids occupies 45-50% it may be time to have the unit pumped. Observe color - Should be Chocolate Brown.
6. Observe if anything appears to be unusual.

b. On-site effluent analysis

1. Sniff the sample for any odor. Sample should not have any “septic smell” if the goal of the unit is to produce a very high quality effluent (low BOD, TSS) and operating properly. If the goal of the unit is to reduce the BOD/TSS substantially, but not necessarily to < 30 mg/L, then there may be slight septic smell.

2. Observe the clarity of the sample. Sample should be relatively clear if the goal is to treat it to BOD/TSS <30 mg/L. If not, there may be some lack of clarity.

3. Check the pH with a small hand held pH meter. It should read between 6.5 and 7.5.

4. Check the dissolved oxygen level. This should be done with minimal agitation to avoid mixing air with the sample. Oxygen levels will vary but levels should be between 1 and 8 mg/L. Higher levels indicates the unit is performing well and low levels <1 mg/L indicates the unit is not performing

adequately. This may be the result of hydraulic/organic overloading, inadequate air supply or poor transfer of oxygen to the water. Those units that aren't expected to treat the effluent to low BOD/TSS levels may have reduced oxygen levels.

5. Temperature of sample. Temperature should be taken immediately.

2. Off-Site analysis:

Further information can be obtained by sending a representative sample to a certified laboratory. This can be somewhat costly and is not necessary for every performance evaluation. It must be done if it appears that the system is not functioning properly based on on-site evaluation.

a. Biochemical oxygen demand. - 5 day test to measure level of oxygen demanding material. BOD should be < 30 mg/L for systems expected to have low BOD.

b. **Total suspended solids** - TSS should be <30 mg/L for systems expected to have low TSS.

c. Nitrogen - TKN, ammonia and nitrate. TKN measures organic and ammonia nitrogen. The TKN and ammonia should be low and nitrates high. During the winters the TKN and ammonia may be a little higher and nitrates a little lower than summer time. TKN and ammonia values should be < 5 and nitrates typically in range of 25-50 mg/L depending on the source of effluent. Nitrates will be lower if unit is a recirculating filter. T

d. Fecal coliforms: measures the level of pathogen reduction via fecal coliform indicators. Numbers will vary depending on type of unit. Single pass sand filter and peat filter effluent will typically have numbers < 1000 col./100 mL. Aerobic units will typically have values that range from < 1000 - 100,000 col./100 mL depending on a number of factors such as degree of treatment, disinfection etc. Recirculating filters will have numbers in range of 1,000 to 100,000 col./100 mL depending on a number of variables. Typical septic tank effluent will have numbers in range of 100,000 to millions col./100 mL.

e. **Alkalinity:** This is a measure of the buffering capacity of the effluent. Sufficient alkalinity must be present for nitrification to occur. Alkalinity is measured as mg/L of $CaCO_3$ (Calcium Carbonate). Typical values for on-site systems range from 250 - 450 mg/L as $CaCO_3$.

Note: It should be noted that ammonia, nitrates and alkalinity are typically evaluated off-site. However, test kits are available for on-site evaluation of these parameters.

C: Testing Equipment/Kits

1. **Dissolved Oxygen Instruments/Kits:**

The following are instruments used for measuring dissolved oxygen:

a. Hach Company, P.O. Box 608, Loveland Colorado. 1-800-227-4224.

Cat. No. 1469-00 - Cost $48

This unit measures oxygen via adding the contents of 3 samples to the sample and using drop count titration and calculating the DO. Takes a few minutes to perform.

b.. Fisher Scientific - 1-800-766-7000.

Cat. No. 13-299-200 Chemets Self Filling Ampules. 0-10mg/L
$49 for 30 tests

This kit measures dissolved oxygen within two minutes. Compare the solution color to a color chart. Takes less time to perform than Hach.

Cat. No. 13-299-415 Single Analyte Meters (SAMs) - Cost $195

This unit measures oxygen via adding the contents of one ample to the sample and read the results on photo detector. Takes less time to perform than Hach.

Cat. No 13-298-56 - YSI Model 55 Hand held dissolved oxygen meter. - $700.

This unit measures both dissolved oxygen and temperature by inserting the probe into the sample or the pump chamber. It has a long cable connecting the probe to the unit. Probe needs to be calibrated and membrane changed periodically. There are other models and more expensive models available.

Note: Dissolved oxygen testing equipment is available through some of the other suppliers listed below.

2. Ammonia, nitrate, pH, settleable solids, alkalinity test kits.

Testing kits and equipment are available from a number of manufacturers: Listed are several sources for obtaining test kits and equipment. Not all sources handle all the materials.

Chemetrics www/chemetrics.com 800 356-3072 Route 28 Calverton, VA 20138	Dissolved oxygen chemet tubes
Cole-Parmer www.coleparmer.com 800 323-4340 625 E. Bunker Ct. Vernon Hills, IL 60061	
Fisher Scientific www.fishersci.com 800 955-6666 4500 Turnberry Drive Hanover Park, IL 60103	
Hach www.hach.com 800 227-4224 PO Box 389 Loveland, CO 80539	Test strips for ammonia, nitrate, pH, Alkalinity
LaMotte www.lamotte.com 800 344-3100 PO Box 329 Chestertown, MD 21620	

PART VI

Alternative Toilets

Outdoor Toilets

The provisions of Chapter 69.13 allow the use of outdoor toilets. The pit should be liquid-tight, with the wastes periodically removed by someone who services septic tanks. The privy should be securely attached to the ground or to the tank used for the pit.

An outdoor toilet can be kept relatively odor-free and can be constructed for year-round use. But while an outdoor toilet is the least costly alternative to a flush toilet, it may be the least desirable alternative for a residence in a northern climate.

An improperly constructed and maintained privy can be an abomination to both eyes and nose. Several methods can be used to minimize the sanitary privy odor problem caused by decomposition of the organic matter in the pit.

- Chemical additives can change the bacterial action so that less odor is generated.
- Both the pit and the upper part of the structure must be vented.
- There should be tight fitting covers on the seat openings.
- Finally, the inside of the structure should be painted with a polyurethane-type paint to minimize the penetration of odors into the wood.

Additives

A number of products on the market claim to minimize odors in a sanitary privy. One that is reasonably effective is hydrated lime. Associated compounds containing the same chemical are slaked lime, quicklime, hot lime, chloride of lime, and pebbled lime.

Approximately one cup of hydrated lime sprinkled over the solids in the pit will minimize odors and aid in decomposition. As the odors again become objectionable another cup of lime should be added. Excess amounts of hydrated lime will retard decomposition, however, rather than promote it, although the generation of odors will be inhibited. Caution should be used to keep the hydrated lime dust out of eyes and nostrils.

Commercial compounds are available and may be tried by the individual owner in order to determine their effectiveness. Some of them are odor suppressants while others change the bacterial environment within the pit.

Ventilation

To minimize odors in the upper part of the privy, vent the pit. Insect-proof openings should be placed in the walls below the seat. A vent should extend from the underside of the seat board through the roof or up to a horizontal vent open to the sides of the toilet. All vent openings to the outside should be properly screened to keep out insects.

The vent must be flush with the underside of the seat board and must not extend down into the pit. Gases which cause odors are lighter than air, and if the vent extends down below the seat board, these gasses will collect under the seat board to be released upward into the privy when the seat cover is opened.

The opening in the seat board must have a tight-fitting cover. The type of seat and cover used on a flush toilet is *not* satisfactory unless weather stripping is added. The cover should be kept in place when the privy is not in use, and can be hinged to close automatically.

At the top of the privy there should be a screened opening on each side or, preferably, all the way around the top to allow air to pass through and carry away any odors which may seep into the upper part of the structure.

A tight-fitting door, preferably with a self-closing feature, such as a spring, should be used to minimize the number of insects that get into the privy. (A crescent-shaped window, also screened, may be cut into the door so that the utility of the structure will be recognized.)

Keeping Wood Odor-Free

Any odors, which in the past have risen into the structure of an old privy, have probably become entrapped in the pores of the wood. To remove these odors, make a solution of disinfectant and trisodium phosphate, and scrub the inside walls and all other inside surfaces of the privy. This solution will remove odors from the pores of the wood. After the wood has dried, paint the inside of the privy with a polyurethane compound to prevent any additional odors from penetrating the wood.

These techniques should minimize the odor that collects in the structure of a sanitary privy. Proper air circulation can be very helpful in carrying away any odors, so proper venting of the structure is absolutely essential.

Even though bacteria are decomposing the organic waste, there will be some residue remaining. This residue will gradually build up until it must either be removed or the structure moved to a new location. Usually a septic tank pumper or someone can remove the solids with equipment to perform the task in a sanitary manner. The frequency of solids removal will depend upon the size of the pit and the amount of use.

Gas Incinerator Toilets

The function of an electric incinerator toilet is essentially the same, except that electrical energy is used for the incineration process.

Incinerator toilets can completely eliminate liquid and solid toilet wastes from the sewage treatment system. The initial cost may vary from $800 to $1,500, including electric wiring and a fireproof vent for the waste gases. Check with your local building official to determine the type of fireproof vent that is required for the installation of an incinerator toilet.

In addition to the initial expense, there may be some replacement costs of component parts for an incinerator toilet. Average energy use is 1.5 pounds of gas or 1.0 kWh for each toilet cycle (flush). Current energy costs can be used to determine the actual use cost.

Because an incinerator toilet requires a cool-down period after each incineration cycle, it may not be a particularly desirable device for a large family where demands on the toilet may come in short spans of time. An incinerator toilet is not particularly effective for situations where there is a considerable amount of liquid waste. Liquid is difficult to burn.

The waste gases from an incinerator toilet have some odor and, under certain atmospheric conditions, may settle to the ground and be objectionable to occupants or neighbors. There have been reports along lakeshore areas, where temperature inversions are common, of incinerator toilets causing serious odor problems. The firepot requires regular cleaning to remove ashes and other residue and will need to be periodically replaced, depending upon the amount of use.

Chemical Toilets

Figure F-1 shows a schematic diagram of a chemical toilet, which is available in many models. In most chemical toilets, a charge of chemical is added to a small amount of water. After use, the liquid is recirculated by an electric- or hand-operated pump to flush the wastes into the holding chamber.

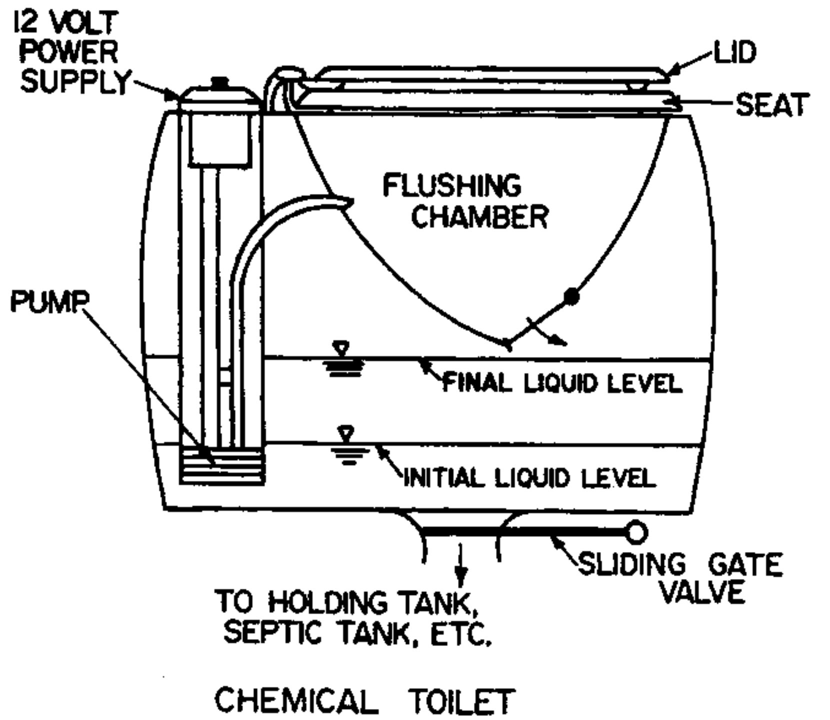


Figure F-1

The initial charge of chemical is adequate for 40 to 160 uses, depending upon the model. When the holding chamber is full, a valve can be opened to discharge wastes into the septic tank. On some chemical toilets, the holding chamber can be removed for disposal of wastes. Wastes are reduced to about two percent of those from a conventional flush toilet.

The initial cost of chemical toilets varies greatly depending on model and size, but it will likely range from $200 to $700 plus installation. The cost of the chemical may be from two to three cents per toilet use. Because most chemical toilets are plastic, they should not corrode. Maintenance costs should be minor.

Composting Toilets

The composting toilet shown in Figure F-2 requires an adjoining room or a cellar for the composting unit. It is also available, however, in a smaller room-sized model as shown in Figure F-3.

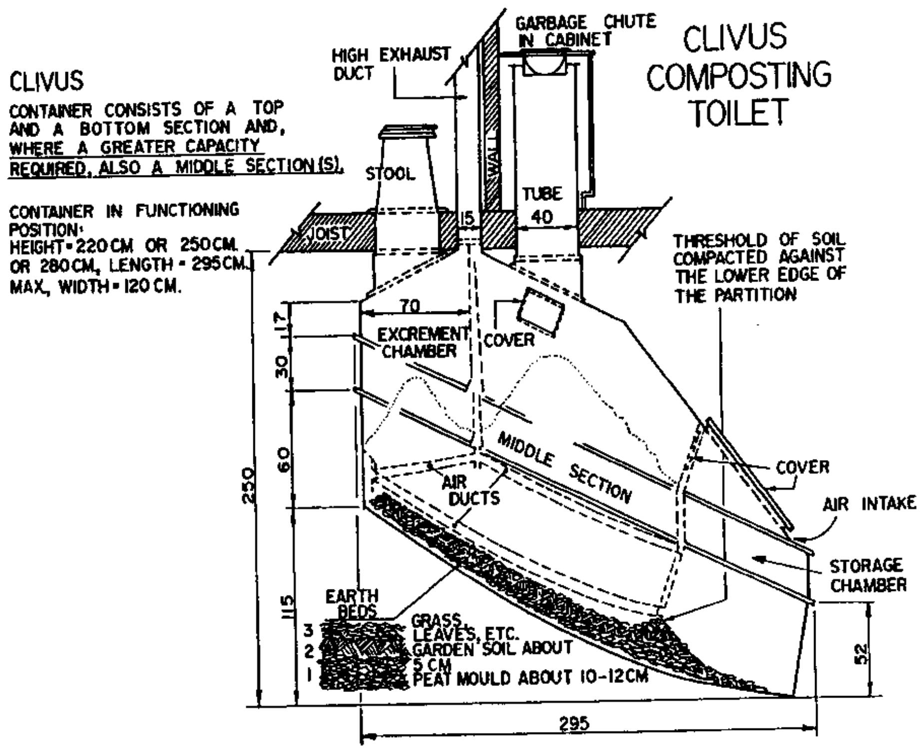


Figure F-2

COMPOSTING TOILET

1. Ventilator Cover with fine-mesh net to prevent flies and insects from entering.
2. Transformer with switch.
3. Fan to evacuate all odor.
4. Distributor to spread input.
5. Heating Coil to warm and evaporate liquid.
6. Thermostat placed inside the heating coil to control the heat level.
7. Collecting Tray to hold decomposed material.
8. Scraper for use when emptying

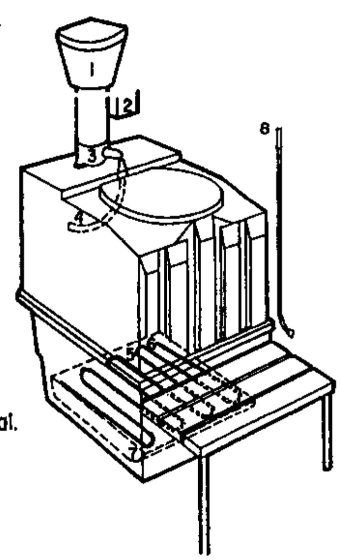


Figure F-3

Composting toilets are more appropriately called **biological toilets** and have two basic principles of operation:

- liquid is evaporated, and
- solid wastes are biologically decomposed into compost.

The biological toilet uses no water and requires no connection to house plumbing.

Every biological toilet has a capacity limit, which depends on its ability to evaporate moisture. To increase the capacity, most room-sized biological toilets use heating elements and fans, together with mixers for the organic material. All biological toilets designed for year-round use must have electricity to run the fan and the heating element. Large-volume biological toilets may be used in seasonal residences without having electricity available, but care must be taken that excess liquid is not discharged into them.

All biological toilets must have the compost removed periodically. The frequency—which depends upon the type of toilet and the number of people using it—might vary from every three weeks to once per year. A biological toilet requires frequent examination and care so that it will continue to function in a satisfactory manner. Care and maintenance requirements vary with the different brands of toilets.

It is advisable to obtain an accurate cost estimate from the supplier of the model you are interested in, as well as information about energy consumption, installation, maintenance and replacement. Energy costs may be appreciable for the year-round use of a composting toilet. The prices of composting toilets may range from $750 to $3,000, plus installation.

Part VII Disinfection:

Attached are 3 articles on disinfection. For more information check out the web.

Onsite Wastewater Treatment Systems Technology Fact Sheet 4

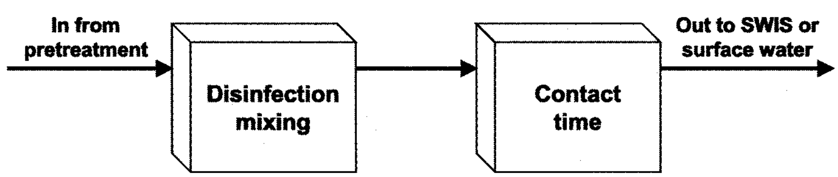
Effluent Disinfection Processes

Description

The process of disinfection destroys pathogenic and other microorganisms in wastewater. A number of important waterborne pathogens are found in the United States, including some bacteria species, protozoan cysts, and viruses. All pretreatment processes used in onsite wastewater management remove some pathogens, but data are scant on the magnitude of this destruction. The two methods described in this section, chlorination and ultraviolet irradiation, are the most commonly used (figure 1). Currently, the effectiveness of disinfection is measured by the use of indicator bacteria, usually fecal coliform. These organisms are excreted by all warm-blooded animals, are present in wastewater in high numbers, tend to survive in the natural environment as long as or longer than many pathogenic bacteria, and are easy to detect and quantify.

A number of methods can be used to disinfect wastewater. These include chemical agents, physical agents, and irradiation. For onsite applications, only a few of these methods have proven to be practical (i.e., simple, safe, reliable, and cost-effective). Although ozone and iodine can be and have been used for disinfection, they are less likely to be employed because of economic and engineering difficulties.

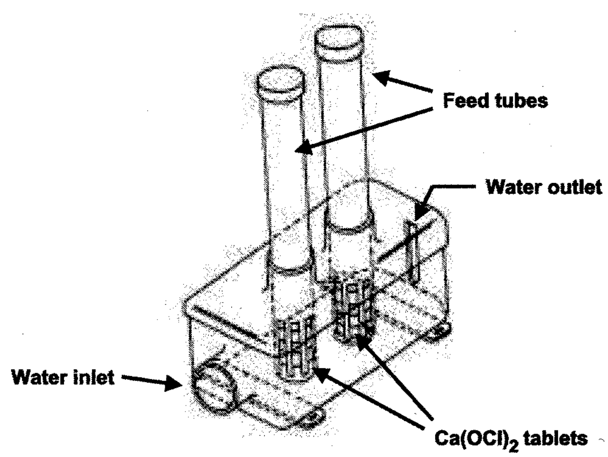
Figure 1. Generic disinfection diagram



Chlorine

Chlorine is a powerful oxidizing agent and has been used as an effective disinfectant in water and wastewater treatment for a century. Chlorine may be added to water as a gas (Cl_2) or as a liquid or solid in the form of sodium or calcium hypochlorite, respectively. Because the gas can present a significant safety hazard and is highly corrosive, it is not recommended for onsite applications. Currently, the solid form (calcium hypochlorite) is most favored for onsite applications. When added to water, calcium hypochlorite forms hypochlorous acid (HOCl) and calcium hydroxide (hydrated lime, $Ca(OH)_2$). The resulting pH increase promotes the formation of the anion, OCl^-, which is a free form of chlorine. Because of its reactive nature, free chlorine will react with a number of reduced compounds in wastewater, including sulfide, ferrous iron, organic matter, and ammonia. These nonspecific side reactions result in the formation of combined chlorine (chloramines), chloro-organics, and chloride, the last two of which are not effective as disinfectants. Chloramines are weaker than free chlorine but are more stable. The difference between the chlorine residual in the wastewater after some time interval (free and combined chlorine) and the initial dose of chlorine is referred to as chlorine demand. The 15-minute chlorine demand of septic tank effluent may range from 30 to 45 mg/L as Cl; for biological treatment effluents, such as systems in Technology Fact Sheets 1, 2, and 3, it may range from 10 to 25 mg/L; and for sand filtered effluent, it may be 1 to 5 mg/L (Technology Fact Sheets 10 and 11).

Figure 2. Example of a stack-feed chlorinator



Calcium hypochlorite is typically dosed to wastewater in an onsite treatment system using a simple tablet feeder device (figure 2). Wastewater passes through the feeder and then flows to a contact tank for the appropriate reaction. The product of the contact time and disinfectant residual concentration (Ct) is often used as a parameter for design of the system. The contact basin should be baffled to ensure that short-circuiting does not occur. Chlorine and combined chlorine residuals are highly toxic to living organisms in the receiving water. Because overdosing (ecological risk) and underdosing (human health risk) are quite common with the use of tablets, long swales/ditches are recommended prior to direct discharge to sensitive waters.

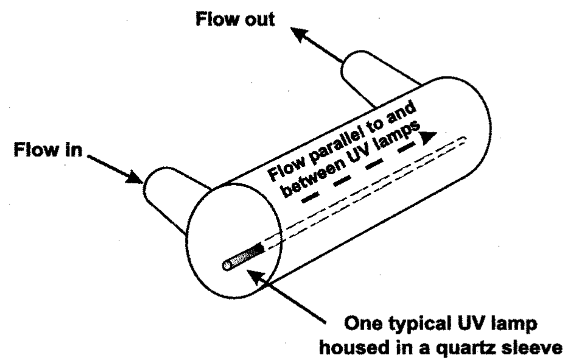
Use of simple liquid sodium hypochlorite (bleach) feeders is more reliable but requires more frequent site visits by operators. These systems employ aspirator or suction feeders that can be part of the pressurization of the wastewater, causing both the pump and the feeder to require inspection and calibration. These operational needs should be met by centralized management or contracted professional management.

Ultraviolet irradiation

The germicidal properties of ultraviolet (UV) irradiation have been recognized for many years. UV is germicidal in the wavelength range of 250 to 270 nm. The radiation penetrates the cell wall of the organism and is absorbed by cellular materials, which either prevents replication or causes the death of the cell. Because the only UV radiation effective in destroying the organism is that which reaches it, the water must be relatively free of turbidity. Because the distance over which UV light is effective is very limited, the most effective disinfection occurs when a thin film of the water to be treated is exposed to the radiation. The quantity of UV irradiation required for a given application is measured as the radiation intensity in microWatt-seconds per square centimeter (mW-s/cm^2). For each application, wastewater transmittance, organisms present, bulb and sleeve condition, and a variety of other factors will have an impact on the mW-s/cm^2 required to attain a specific effluent microorganism count per 100 mL. The most useful variable that can be readily controlled and monitored is Total Suspended Solids. TSS has a direct impact on UV disinfection, which is related to the level of pretreatment provided.

Many commercial UV disinfection systems (figure 3) are available in the marketplace. Each has its own approach to how the wastewater contacts UV irradiation, such as the type of bulb (medium or low pressure; medium, low, or high intensity), the type of contact chamber configuration (horizontal or vertical), or the sleeve material separating the bulb from the liquid (quartz or teflon). All can be effective, and the choice will usually be driven by economics.

Figure 3. Wastewater flow in a quartz UV unit



Typical applications

Disinfection is generally required in three onsite-system circumstances. The first is after any process that is to be surface discharged. The second is before a SWIS where there is inadequate soil (depth to ground water or structure too porous) to meet ground water quality standards. The third is prior to some other immediate reuse (onsite recycling) of effluent that stipulates some specific pathogen requirement (e.g., toilet flushing or vegetation watering).

Design assumptions

Chlorination units must ensure that sufficient chlorine release occurs (depending on pretreatment) from the tablet chlorinator. These units have a history of erratic dosage, so frequent attention is required. Performance is dependent on pretreatment, which the designer must consider. At the point of chlorine addition, mixing is highly desirable and a contact chamber is necessary to ensure maximum disinfection. Working with chlorinator suppliers, designers should try to ensure consistent dosage capability, maximize mixing usually by chamber or head loss, and provide some type of pipe of sufficient length to attain effective contact time before release. Tablets are usually suspended in open tubes that are housed in a plastic assembly designed to increase flow depth (and tablet exposure) in proportion to effluent flow. Without specific external mixing capability, the contact pipe (large-diameter Schedule 40 PVC) is the primary means of accomplishing disinfection. Contact time in these pipes (often with added baffles) is on the order of 4 to 10 hours, while dosage levels are in excess of those stated in table 1 for different pretreatment qualities and pH values. The commercial chlorination unit is generally located in a concrete vault with access hatch to the surface. The contact pipe usually runs from the vault toward the next step in the process or discharge location. Surface discharges to open swales or ditches will also allow for dechlorination prior to release to a sensitive receiving water.

Table 1. Chlorine disinfection dose (in mg/L) design guidelines for onsite applications

Calcium hypochlorite	Septic tank effluent	Biological treatment effluent	Sand filter effluent
pH 6	35–50	15–30	2–10
pH 7	40–55	20–35	10–20
pH 8	50–65	30–45	20–35

Note: Contact time = 1 hour at average flow and temperature 20 °C. Increase contact time to 2 hours at 10 °C and 8 hours at 5 °C for comparable efficiency. Dose = mg/L as Cl. Doses assume typical chlorine demand and are conservative estimates based on fecal coliform data.

The effectiveness of UV disinfection is dependent upon UV power (table 2), contact time, liquid film thickness, wastewater absorbance, wastewater turbidity, system configuration, and temperature. Empirical relationships are used to relate UV power (intensity at the organism boundary) and contact time. Table 2 gives a general indication of the dose requirements for selected pathogens. Since effective disinfection is dependent on wastewater quality as measured by turbidity, it is important that pretreatment provide a high degree of suspended and colloidal solids removal.

Table 2. Typical ultraviolet (UV) system design parameters

Design parameter	Typical design value
UV dosage	20–140 mW-s/cm^2
Contact time	6–40 seconds
UV intensity	3–12 mW-s/cm^2
Wastewater UV transmittance	50–70%
Wastewater velocity	2–15 inches per second

Commercially available UV units that permit internal contact times of 30 seconds at peak design flows for the onsite system can be located in insulated outdoor structures or in heated spaces of the structure served, both of which must protect the unit from dust, excessive heat, freezing, and vandals. Ideally, the unit should also provide the necessary UV intensity (e.g., 35,000 to 70,000 mW-s/cm^2) for achieving fecal coliform concentrations of about 200 CFU/100 mL. The actual dosage that reaches the microbes will be reduced by the transmittance of the wastewater (e.g., continuous-flow suspended-growth aerobic systems [CFSGAS] or fixed-film systems [FFS] transmittance of 60 to 65 percent). Practically, septic tank effluents cannot be effectively disinfected by UV, whereas biological treatment effluents can meet a standard of 200 cfu/100 mL with UV. High-quality reuse standards will require more effective pretreatment to be met by UV disinfection. No additional contact time is required. Continuous UV bulb operation is recommended for maximum bulb service life. Frequent on/off sequences in response to flow variability will shorten bulb life. Other typical design parameters are presented in table 2.

Performance

There are few field studies of tablet chlorinators, but those that exist for post-sand-filter applications show fecal coliform reductions of 2 to 3 logs/100 mL. Another field study of tablet chlorinators following biological treatment units exceeded a standard of 200 FC/100 mL
93 percent of the time. No chlorine residual was present in 68 percent of the samples. Newer units managed by the biological unit manufacturer fared only slightly better. Problems were related to TSS accumulation in the chlorinator, tablet caking, failure of the tablet to drop into the sleeve, and failure to maintain the tablet supply. Sodium hypochlorite liquid feed systems can provide consistent disinfection of sand filter effluents (and biological system effluents) if the systems are managed by a utility.

Data for UV disinfection for onsite systems are also inadequate to perform a proper analysis. However, typical units treating sand filter effluents have provided more than 3 logs of FC removal and more than 4 logs of poliovirus removal. Since this level of pretreatment results in a very low final FC concentration (<100 CFU/100 mL), removals depend more on the influent concentration than inherent removal capability. This is consistent with several large-scale water reuse studies that show that filtered effluent can reach essentially FC-free levels (<1 CFU/100 mL) with UV dosage of about 100 mW-s/cm^2, while higher (but attainable) effluent FC levels require less dosage to filtered effluent (about 48 mW-s/cm^2) than is required by aerobic unit effluent (about 60 mW-s/cm^2). This can be attributed to TSS, turbidity, and transmittance (table 3). Average quartz tube transmittance is about 75 to 80 percent.

Table 3. Typical (UV) transmittance values for water

Wastewater treatment level	Percent transmittance
Primary	45–67
Secondary	60–74
Tertiary	67–82

Source: USEPA, 1986.

Management needs

Chlorine addition by tablet feeders is likely to be the most practical method for chlorine addition for onsite applications. Tablet feeders are constructed of durable, corrosion-free plastics and are designed for in-line installation. Tablet chlorinators come as a unit similar to figure 2. If liquid bleach chlorinators are used, they would be similarly constructed. That unit is placed inside a vault that exits to the contact basin. The contact basin may be plastic, fiberglass, or a length of concrete pipe placed vertically and outfitted with a concrete base. Baffles should be provided to prevent short-circuiting of the flow. The contact basin should be covered to protect against the elements, but it should be readily accessible for maintenance and inspection.

The disinfection system should be designed to minimize operation and maintenance requirements, yet ensure reliable treatment. For chlorination systems, routine operation and maintenance would include servicing the tablet or solution feeder equipment, adding tablets or premixed solution, adjusting flow rates, cleaning the contact tank, and collecting and analyzing effluent samples for chlorine residuals. Caking of tablet feeders may occur and will require appropriate maintenance. Bleach feeders must be periodically refilled and checked for performance. Semiskilled technical support should be sufficient, and estimates of time are about 6 to 10 hours per year. There are no power requirements for gravity-fed systems. Chemical requirements are estimated to be about 5 to 15 pounds of available chlorine per year for a family of four. During the four or more inspections required per year, the contact basin may need cleaning if no filter is located ahead of the unit. Energy requirements for a gravity-fed system are nil. If positively fed by aspirator/suction with pumping, the disinfection unit and alarms for pump malfunctions will use energy and require inspection. Essentially unskilled (but trained) labor may be employed. Safety issues are minimal and include wearing of proper gloves and clothing during inspection and tablet/feeder work.

Commercially available package UV units are available for onsite applications. Most are self-contained and provide low-pressure mercury arc lamps encased by quartz glass tubes. The unit should be installed downstream of the final treatment process and protected from the elements. UV units must be located near a power source and should be readily accessible for maintenance and inspection. Appropriate controls for the unit must be corrosion-resistant and enclosed in accordance with electrical codes.

Routine operation and maintenance for UV systems involves semiskilled technician support. Tasks include cleaning and replacing the UV lamps and sleeves, checking and maintaining mechanical equipment and controls, and monitoring the UV intensity. Monitoring would require routine indicator organism analysis. Lamp replacement (usually annually) will depend upon the equipment selected, but lamp life may range from 7,500 to 13,000 hours. Based on limited operational experience, it is estimated that 10 to 12 hours per year would be required for routine operation and maintenance. Power requirements may be approximately 1 to 1.5 kWh/d. Quartz sleeves will require alcohol or other mildly acidic solution at each (usually four per year) inspection.

Whenever disinfection is required, careful attention to system operation and maintenance is necessary. Long-term management, through homeowner-service contracts or local management programs, is an important component of the operation and maintenance program. Homeowners do not possess the skills needed to perform proper servicing of these units, and homeowner neglect, ignorance, or interference may contribute to malfunctions.

Risk management issues

With proper management, the disinfection processes cited above are reliable and should pose little risk to the homeowner. As mentioned above, a potentially toxic chlorine residual may have an important environmental impact if it persists at high concentrations in surface waters. By-products of chlorine reactions with wastewater constituents may also be toxic to aquatic species. If dechlorination is required prior to surface discharge, reactors containing sulfur dioxide, sodium bisulfate, sodium metabisulfate, or activated carbon can be employed. If the disinfection processes described above are improperly managed, the processes may not deliver the level of pathogen destruction that is anticipated and may result in some risk to downstream users of the receiving waters. The systems described are compact and require modest attention. Chlorination does not inherently require energy input; UV irradiation and dosage pumps do consume some energy

(>1kWh/day). Both processes will require skilled technical support for the monitoring of indicator organisms in the process effluents.

Chlorination systems respond to flow variability if the tablets are feeding correctly. UV does not do so and is designed for the highest flow scenario, thus overdosing at lower flows since there is no danger in doing so. Toxic loads are unlikely to affect either system, but TSS can affect both. Inspections must include all pretreatment steps. UV is more sensitive to extreme temperatures than chlorination, and must be housed appropriate to the climate. In extremely cold climates, the UV system can be housed inside the home with minimal danger to the inhabitants. Power outages will terminate UV disinfection and pressurized pumps for both systems, while causing few problems for gravity-fed chlorination units. There should be no odor problems during these outages.

Costs

Installed costs of a complete tablet chlorination unit are about $400 to $500 for the commercial chlorinator unit and associated materials and $800 to $1,200 for installation and housing. Operation and maintenance would consist of tablets ($30 to $50 per year), labor ($75 to $100 per year), and miscellaneous repairs and replacements ($15 to $25 per year), in addition to any analytical support required.

Installed costs of UV units and associated facilities are $1,000 to $2,000. O/M costs include power ($35 to $40 per year), semiskilled labor ($50 to $100 per year), and lamp replacement ($70 to $80 per year), plus any analytical support.

References

Bauer, D.H., E.T. Conrad, and D.G. Sherman. 1981. *Evaluation of Onsite Wastewater Treatment and Disposal Options*. EPA 600/S2-81-178. NTIS No. PB-82-101-635. National Technical Information Service, Cincinnati, OH.

Crites, R., and G. Tchobanoglous. 1998. *Small and Decentralized Wastewater Management Systems*. WCB/McGraw-Hill, San Francisco, CA.

Hanzon, B.D., and R. Vigilia. 1999. Just the facts. *Water Environment and Technology* November 1999, 34-42.

Scheible, O.K. 1987. Development of a rationally based design protocol for the ultraviolet light disinfection process. *Journal of the Water Pollution Control Federation* 59:25.

University of Wisconsin. 1978. *Management of Small Waste Flows*. EPA 600/2-78-173. Cincinnati, OH.

U.S. Environmental Protection Agency (USEPA). 1980. *Design Manual: Onsite Wastewater Treatment and Disposal Systems*. EPA 625/1-80-0012. U.S. Environmental Protection Agency, Cincinnati, OH.

U.S. Environmental Protection Agency (USEPA). 1986. *Municipal Wastewater Disinfection Design Manual.* EPA 625/1-86-021. U.S. Environmental Protection Agency, Cincinnati, OH.

U.S. Environmental Protection Agency (USEPA). 1992.*Ultraviolet Disinfection Technology Assessment.* EPA-832/R-92-004. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

Water Environment Federation. 1998. *Design of Municipal Wastewater Treatment Plants,* 3d ed. Alexandria, VA.

White, G.C. 1992. *The Handbook of Chlorination and Alternative Disinfectants.* 3d ed. Van Nostrand Reinhold, New York.

Texas Agricultural Extension Service
THE TEXAS A&M UNIVERSITY SYSTEM

L-5344
6-00

On-site wastewater treatment systems

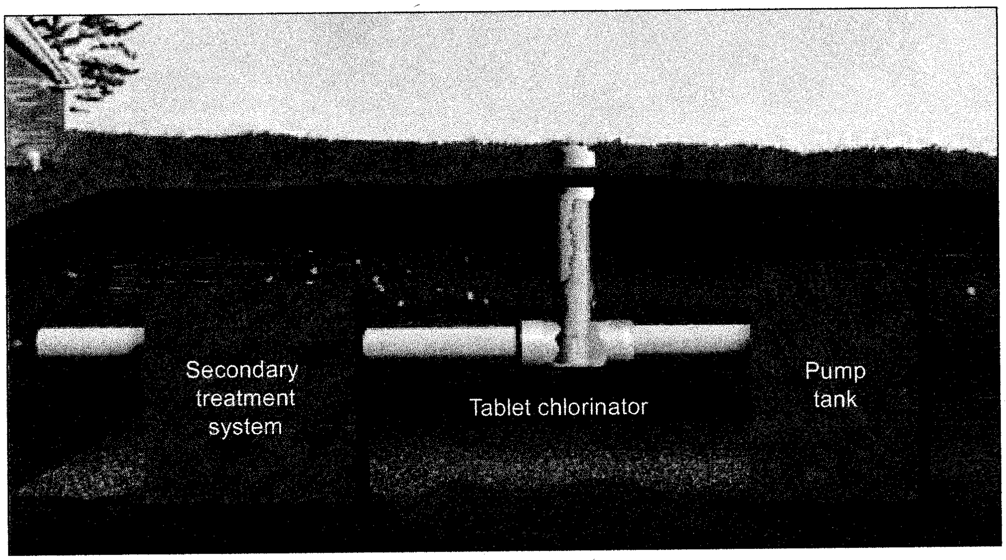


Figure 1: The most common form of disinfection for on-site systems is tablet chlorination.

Tablet chlorination

Richard Weaver and Bruce Lesikar
Professor in Soil and Environmental Microbiology, Extension Agricultural Engineering Specialist
The Texas A&M University System

Wastewater that is sprayed onto lawns must first be disinfected to prevent odors and remove disease-causing microorganisms. Wastewater can be disinfected with chlorine, ozone and ultraviolet light. For on-site wastewater treatment systems, the most common form of disinfection is tablet chlorination.

Tablet chlorinators generally have four components:

- ✓ Chlorine tablets.
- ✓ A tube that holds the tablets.
- ✓ A contact device, which puts the chlorine tablets into contact with the wastewater.
- ✓ A storage reservoir, usually a pump tank, where the wastewater is stored before it is distributed.

Before being chlorinated, wastewater from a home is treated by a secondary treatment device, usually in an aerobic treatment unit or sand filter. The wastewater moves from the treatment device through a pipe to the contact device.

The contact device usually contains a basin, where the tube containing a stack of chlorine tablets is placed. The bottom tablet in the tube is in contact with the wastewater flowing through the basin. As that tablet dissolves and/or erodes, the tablet above it falls by gravity to replace it.

A tablet can dissolve quickly or slowly, depending on the amount of wastewater coming into contact with

Use only chlorine tablets that are approved for wastewater

it and the length of time it is in contact. A balance must be struck regarding the contact time in the chlorinator basin: Too much contact time causes the wastewater to be over-chlorinated and the tablets to be consumed rapidly; too little contact time, and the wastewater is not chlorinated enough.

Use only chlorine tablets that are approved for use in wastewater. They are made of calcium hypochlorite, a common household bleach. These tablets dissolve in the wastewater, releasing the hypochlorite, which then becomes hypochlorous acid, the primary disinfectant.

Do not use swimming pool chlorine tablets. They are often made from trichloroisocyanuric acid, which is not approved for use in wastewater treatment systems. These tablets make the chlorine available too slowly for it to be effective. If wetted repeatedly, they also can produce nitrogen chloride, which can explode.

Do not combine tablets of trichloroisocyanuric acid with calcium hypochlorite, because the combination will form the explosive compound nitrogen chloride. Read the list of active ingredients on the tablet label to make sure you are using calcium hypochlorite.

Because chlorine tablets are caustic, handle them with care. Wear gloves to protect your skin from direct contact with the tablets. Moist tablets are the most caustic; handle them with special care.

Also, because chlorine gas collects in the tablet container, open the container in a well-ventilated area. Chlorine gas can escape from the tablets and container, reducing the effectiveness of the tablets and possibly corroding metal products stored near the container.

After being chlorinated, the wastewater enters the pump tank, where the disinfection process is completed. At this point the wastewater is called reclaimed water. Texas regulations require that reclaimed water contain at least 0.2 milligrams of chlorine per liter of wastewater or have no more than 200 fecal coliforms (bacteria from human wastes) per 100 milliliters of wastewater.

An easy way to determine the chlorine concentration in your reclaimed water is by using chlorine test kits. They are available in stores that sell swimming pool supplies.

The most satisfactory kits require that you mix a small amount of reclaimed water in a solution and compare the mixture's color with those shown in the kit. The kits using paper strips may be less satisfactory because they do not determine the actual concentration of chlorine in the water.

Usually, if a test detects any chlorine, the wastewater will contain less than 200 fecal coliforms per 100 milliliters. But this does not guarantee that it is free of disease-causing organisms. To reduce the risk of having any disease-causing organisms, the wastewater should have at least 0.2 milligrams of chlorine per liter.

How to keep it working

You can either buy a chlorinator commercially or have one built by an installer. Please follow the manufacturer's recommendations for maintaining the system. Other guidelines:

- ✓ Make sure the chlorinator contains chlorine tablets at all times. Inspect it weekly to ensure that tablets are present and in

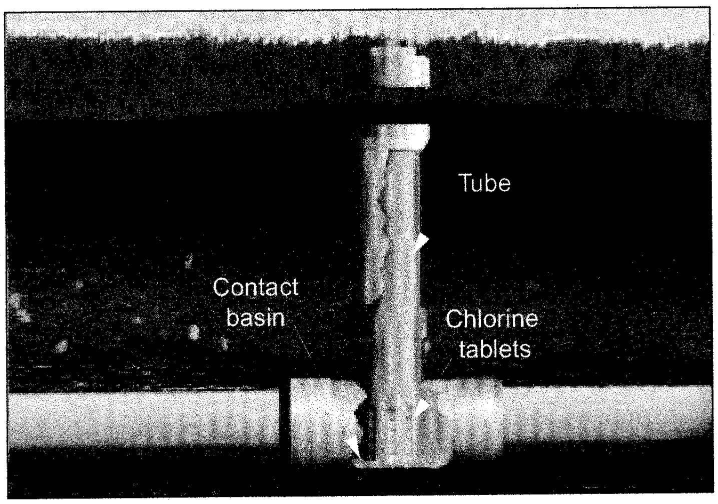


Figure 2: Wastewater disinfection begins in the contact basin.

contact with the wastewater. Add chlorine tablets as necessary. Just as cars do not operate without gasoline, tablet chlorinators do not operate without chlorine tablets.

✓ If you use a spray distribution system, Texas regulations require that you keep a maintenance contract in effect with a licensed maintenance provider. Most such contracts stipulate that the homeowner replace the chlorine tablets.

✓ Tablets can become compacted in the tube. To reduce the chances of compaction, place two to five tablets in the tube at a time.

✓ If the tablets do become compacted in the tube, or if a portion of the bottom tablet has not dissolved and is holding up the rest of the stack, remove the tube and wash out the blockage with a stream of water from a garden hose.

✓ Use only tablets that have been certified for use in domestic wastewater systems. State regulations do not allow tablets for swimming pools and other applications to be used to treat wastewater.

✓ Use a chlorine test kit to determine the chlorine concentration in the pump tank.

✓ If you smell septic odors when the reclaimed water is being sprayed, check to make sure that the chlorinator contains chlorine tablets. If it does, contact your maintenance provider to check the system.

Tablet chlorinators do not operate without chlorine tablets

Ultraviolet Disinfection

Project funded by the U.S. Environmental Protection Agency under Assistance Agreement No. CX824652

Fact Sheet

What is disinfection?

Human exposure to wastewater discharged into the environment has increased in the last 15 to 20 years with the rise in population and the greater demand for water resources for recreation and other purposes. Wastewater is disinfected to prevent the transmission of infectious diseases and to ensure that water is safe for human contact and the environment. There is no perfect disinfectant. However, there are certain characteristics to look for when choosing the most suitable disinfectant:

- ability to penetrate and destroy infectious agents under normal operating conditions;
- lack of characteristics that could be harmful to people and the environment;
- safe and easy handling, shipping, and storage;
- absence of toxic residuals, such as cancer-causing compounds, after disinfection; and
- affordable capital and operation and maintenance (O&M) costs.

What is UV disinfection?

One way to disinfect wastewater is through ultraviolet (UV) radiation, which inactivates disease-causing bacteria by electromagnetic radiation. Wastewater flows through or around a tube with UV light penetrating it from all directions. Radiation is transferred to the cell walls of the bacteria, rendering the organisms sterile.

A UV disinfection system consists of mercury arc lamps, a reactor, and ballasts. The lamps are the source of UV radiation, the ballasts provide power to the system, and wastewater flows through tubes in the reactor. Two types of mercury lamps can be used: low pressure or medium pressure.

There are two types of UV disinfection reactor configurations: contact and noncontact. In both of these types, wastewater can flow either perpendicular or parallel to the lamps. Figure 1 (see page 2) shows two UV contact reactors with submerged lamps placed parallel and perpendicular to the direction of the wastewater flow. In the noncontact reactor, the UV lamps are suspended outside of a clear conduit. Flap gates or weirs are used to control the level of the wastewater.

What are the advantages and disadvantages of using UV disinfection?

Advantages

- UV disinfection is effective at inactivating most viruses, spores, and cysts.
- UV disinfection is a physical process rather than a chemical disinfectant; thus eliminating the need to generate, handle, transport, or store toxic/hazardous or corrosive chemicals.
- There are no toxic residuals that could be harmful to humans or aquatic life.
- UV is user-friendly for operators.
- The wastewater needs to be in contact with UV light for only a short time to be adequately disinfected (approximately 20 to 30 seconds with low-pressure lamps).
- UV disinfection equipment requires less space than other methods.

Disadvantages

- Low dosages may not effectively inactivate some viruses, spores, and cysts.
- Organisms can sometimes repair themselves and "undo" the effects of UV disinfection. This phenomenon is known as *photoreactivation*.
- The tubes used to carry the wastewater can develop a buildup of slime, or fouling, which may require regular cleaning for preventive maintenance.
- It is more difficult to penetrate microorganisms in wastewater that is not clear (containing high amount of solids in suspension).
- In some cases, UV can be more expensive than other disinfection methods.
- There is no measurable residual to indicate the effectiveness of UV disinfection.

What determines the performance of UV disinfection systems?

A UV disinfection system must be designed to reach the most bacteria with the

continued—

This fact sheet was developed by Clement Solomon, Peter Casey, Colleen Mackne, and Andrew Lake.

WWFSGN98

ETI
Environmental Technology Initiative

A General Overview

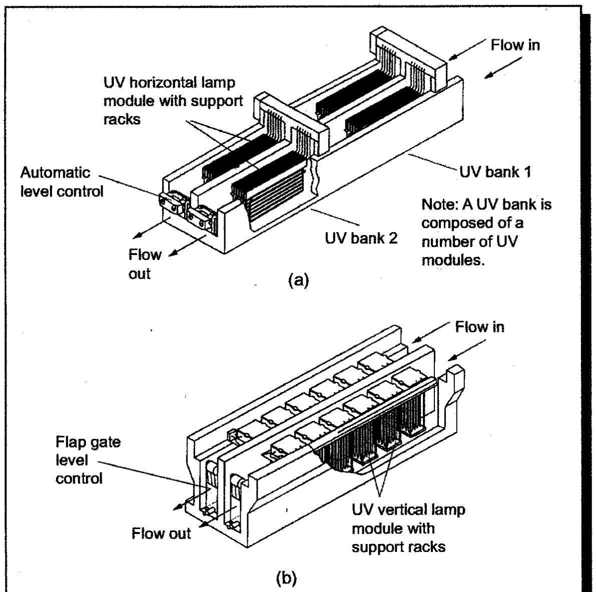


Figure 1:
Isometric cut-away views of typical UV disinfection systems with cover grating removed: (a) horizontal lamp system parallel to flow (adapted from Trojan Technologies, Inc.) and (b) vertical lamp system perpendicular to flow (adapted from Infilco Degremont, Inc.)

Source: Crites and Tchobanoglous (1998), used with permission from The McGraw-Hill Companies

strongest UV dose for the longest time possible. The success of UV disinfection depends on the amount of time the wastewater is exposed to UV radiation, the intensity of UV radiation, and the characteristics of the particular wastewater at the time of disinfection. The amount and type of microorganisms vary with different wastewater. The concentration of total suspended solids and of particle-associated microorganisms determines how much UV radiation ultimately reaches the target organisms. The higher these concentrations are, the lower the UV radiation absorbed by the organisms, and thus, the less effective disinfection can be.

Are UV disinfection systems easy to operate and maintain?

Proper O&M is needed to keep a UV system functioning at maximum performance. This requires that all surfaces between the UV radiation and the target organisms be kept clean—mainly the tubes, lamps, and reactor. Inadequate cleaning is one of the most common causes for a UV system's failure to perform.

O&M also involves replacing the tubes, lamps, or quartz sleeves regularly, according to manufacturer's instructions. Lamps are generally replaced after 12,000 hours of use, quartz sleeves after 5 to 8 years, and ballasts every 10 to 15 years.

What is the cost of UV disinfection?

The cost of UV disinfection systems depends on the manufacturer, the site, the capacity of the plant, and the characteristics of the wastewater to be disinfected. The main operating costs are power consumption, equipment replacement and repairs, cleaning supplies, and personnel costs.

Typical (total) O&M costs per year for each low-pressure lamp range from $85 to $98, which includes these items: power; replacement of lamps, ballasts, and sleeves; cleaning chemicals and supplies; staffing requirements; and miscellaneous equipment repairs.

How do I stay informed about UV technology?

For more information on UV disinfection or a list of other fact sheets, contact the National Small Flows Clearinghouse (NSFC) at West Virginia University, P.O. Box 6064, Morgantown, WV 26506-6064. Phone: (800) 624-8301 or (304) 293-4191. Fax: (304) 293-3161. World Wide Web site: *http://www.nsfc.wvu.edu.*

The NSFC provides free and low-cost informational services and products to help homeowners and small communities address their wastewater needs. Also, information about manufacturers, consultants, regulations, and facilities can be obtained from the NSFC's databases.

References

Crites, R. and G. Tchobanoglous. 1998. *Small and Decentralized Wastewater Management Systems.* The McGraw-Hill Companies. New York, New York.

Darby, J.; M. Heath; J. Jacangelo; F. Loge; P. Swaim; and G. Tchobanoglous. 1995. *Comparison of UV Irradiation to Chlorination: Guidance for Achieving Optimal UV Performance.* Water Environment Research Foundation. Alexandria, Virginia.

Metcalf & Eddy, Inc. 1991. *Wastewater Engineering: Treatment, Disposal, and Reuse.* 3d ed. The McGraw-Hill Companies. New York, New York.

Task Force on Wastewater Disinfection. 1986. *Wastewater Disinfection.* Manual of Practice No. FD-10. Water Pollution Control Federation. Alexandria, Virginia.

U.S. Environmental Protection Agency (EPA). 1986a. *Design Manual: Municipal Wastewater Disinfection.* EPA Office of Research and Development. Cincinnati, Ohio. EPA/625/1-86/021.

———. 1986b. "Disinfection with Ultraviolet Light—Design, Construct, and Operate for Success." EPA. Cincinnati, Ohio.

———. 1988. "Ultra Violet Disinfection: Special Evaluation Project." EPA Region 5. Chicago, Illinois.